EVALUATION OF STRENGTH CHARACTERISTICS OF WINGER PIT AND CRAWFORD PIT GRAVELS AND THE INFLUENCE OF ADDITIVES UPON THE PLASTICITY CHARACTERISTICS OF CRAWFORD GRAVEL FINES

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APRIL 1959

THE UNIVERSITY OF ALBERTA

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A DISSERTATION

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR

THE DEGREE OF MASTER OF SCIENCE

FACULTY OF ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING

BY

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April, 1959.

THE UNIVERSITY OF ALBERTA
FACULTY OF GRADUATE STUDIES

The undersigned hereby certify that they have read and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled

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submitted by Kenneth Arthur Millions, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

Professor

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April, 1959.

ACKNOWLEDGMENTS

The author wishes to extend his appreciation to:

Associate Professor S.R. Sinclair for his constructive criticism and helpful guidance throughout the investigation.

The Highways Division of the Department of Public Works of Canada, under whose sponsorship the author carried out the investigation.

Mr. A. Jacobs and Mr. G. Buxton, of the Banff Laboratory of the Department of Public Works, who voluntarily relinquished their annual vacations in order to assist in all phases of the testing programme.

The Department of Highways, Province of Alberta, for their co-operation in supplying the aggregate and background information used in the investigation.

ABSTRACT

The strength characteristics of Winger Pit and Crawford Pit gravels were investigated in a vacuum triaxial testing programme, using specimens 12 inches in diameter by 24 inches high and gravel sizes up to 3 inches. The effects upon the strength of Winger Pit gravel produced by variations in moisture content and by crushing and washing were evaluated. In addition, an evaluation was made of the effects upon the strength of Crawford Pit gravel brought about by the addition of a small quantity of portland cement.

An investigation was also made into the effect with time upon the plasticity characteristics of the fines of Crawford Pit gravel produced by the addition of cement and of lime and fly-ash.

It was found that:

a) The loss of strength of a gravel, containing an excess of plastic fines, due to an increase in moisture content, results from the low permeability of the gravel.

b) The permeability of such gravel may be increased by screening, washing, or by the addition of a trace quantity of portland cement.

c) Crushing of the gravel produces an increase in stability at failure strain, but does not prevent a reduction in stability due to an increase in moisture content.

d) Both cement and lime and fly-ash produce an immediate reduction of the plasticity index of the Crawford gravel fines. With both additives the Plasticity Index of the fines remains relatively constant after the initial reduction. As curing takes place, the Liquid and Plastic Limits increase with time. This is more noticeable with the cement additive than with the lime and fly-ash.

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CHAPTER I

PURPOSE, HISTORY AND PREVIEW OF INVESTIGATION

In many parts of Canada, and particularly throughout the Prairie Provinces, known sources of good quality, well graded, clean gravel, for use as highway base course, are rapidly being depleted. This is occurring at a time when, due to increasing thicknesses of base course required to support higher legal truck loads, and to much wider highways being built to accommodate the traffic of today and of the future, vastly higher quantities of gravel are required per mile of highway than was thought necessary as recently as ten years ago. In addition to this, the highway departments are attempting to surface most of their highways with either flexible or rigid pavements; highways which 15 years ago would have remained unpaved. This has meant that it has been necessary to use marginal and sub-marginal gravels for base courses where good quality gravels have not been found within economical hauling distance of a paving project. In some cases, little or no difficulty was experienced in using these poorer gravels, but more often than not, failures in the pavement, ranging from a few localized areas to miles of highway, have occurred and which have been attributed, wholly or in part, to lack of stability within the base course gravel.

One of the two phases of this investigation was to attempt to determine whether or not the stability of Winger Pit gravel*, which had an excess of low plastic fines, could be improved by crushing to various maximum sizes or by removing a portion of the fines, as would be accomplished in the field by washing. Crawford Pit gravel** was used in the second phase of the investigation. An attempt was made to determine the effect produced

*Winger Pit (SW-14-30-1-W.5) near Carstairs, Alberta
**Crawford Pit (SW-33-36-20-W.4) near Stettler, Alberta

upon the medium plastic fines of this gravel by the addition of small amounts of portland cement, and of lime and fly-ash. Triaxial tests were also run on the second gravel before and after the addition of cement to determine the effect of the cement upon the stability of the gravel.

The history of the base course where Winger pit gravel was used is as follows. The 3 inch crushed gravel was used as a base course when constructing Alberta highway number 2 in the summer of 1956, and was employed for base from mile 35 to mile 43 north of Calgary. The gravel was compacted in 6 inch lifts over the compacted subgrade at optimum moisture content until the full height of approximately 12 inches was obtained. It was then covered with two inches of 3/4 inch crushed Winger gravel and two inches of plant mixed 3/4 inch crushed asphalt stabilized base. The cutback asphalt used was an MC4 grade. This usually was carried out within a day or two of the completion of a section of 3 inch base.

The side slopes of the 3 inch base, approximately 3 feet wide, were not protected with the asphalt stabilized base and consequently became saturated during heavy summer rains. The excess moisture in these slopes gradually migrated by capillary action toward the centre of the roadway. This was determined by a definite increasing moisture content gradient in the base course between the centre of the roadway and the sides.*

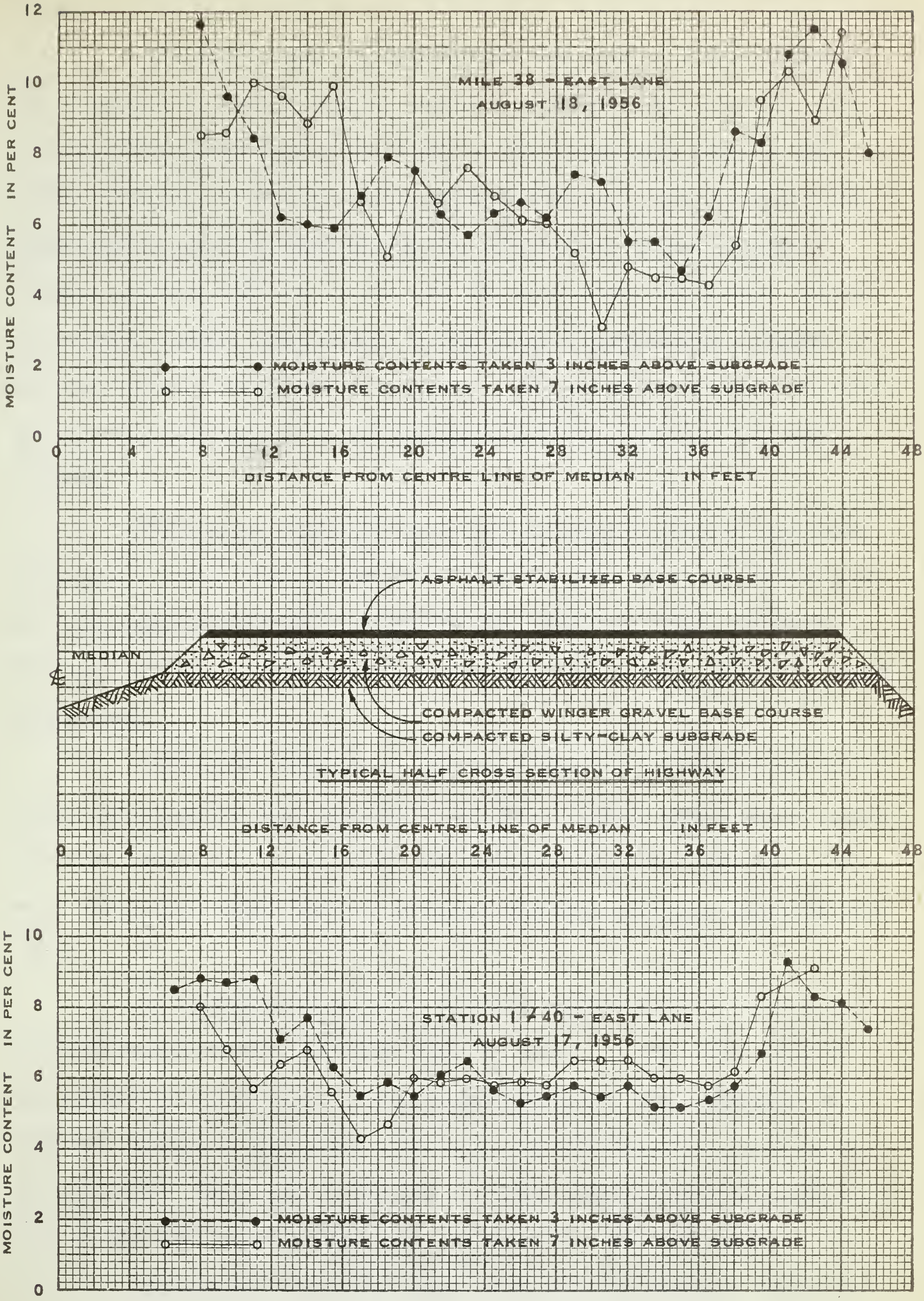
The increase in moisture content, with a resulting loss of stability, was first noticed when the shoulders of the highway commenced to fail under construction loads. Within a short time failure was general in the shoulder areas. Little distress in the centre section of the road was noted at this time.

The condition was remedied by ripping the base course, aerating it to dry it to less than optimum moisture content, stabilizing it with an MC2 cutback asphalt and compacting it back into place. The base since then, has been covered with 4 inches of asphaltic concrete pavement, which has been surface treated, and virtually no sign of distress has been noted to

* See Figure A

FIGURE A

FIELD MOISTURE CONTENTS, AFTER A RAIN STORM, OF WINGER GRAVEL COMPACTED NEAR OPTIMUM MOISTURE CONTENT



date.

The gravel from the Crawford pit was used as a base course for a section of Alberta highway number 12 near Stettler, Alberta. Due to the medium plasticity of the fines in the gravel, this material was rather difficult to dry to optimum moisture content. This condition was aggravated by the fact that during the construction season frequent showers occurred with the result that the base course was placed, ripped and aerated several times before it was finally covered with 2 inches of 3/4 inch asphalt stabilized base course. The net effect of this re-working was to cause segregation of the aggregate and the final base was not uniform.

Failure in this base course had occurred in several localized areas and in every case it was found that the base below the failed area was both excessively high in fines, and wet. Adjacent areas, where the base material was coarser and at optimum moisture content, showed no signs of distress.

Corrective measures in this case involved excavating the failed areas, replacing the base material with similar gravel compacted at optimum moisture content, and covering the new base with asphaltic material. No major areas have shown signs of failure since the corrective measures were taken.

As aggregate sizes up to 3 inches maximum were to be used in strength determinations, in order that the effect of the whole range of sizes might be considered , it was assumed that the large aggregate in a test specimen would negate the results of any semi-empirical, penetration type, strength tests such as the C.B.R. Other commonly used strength tests, such as the Hveen stabilometer, were rejected for the same reason.

Unconfined compression tests on a granular material cannot be

satisfactorily carried out. Thus the triaxial shear test was decided upon for use in the strength investigation. This test, while not as easily carried out as the unconfined, does give more information than the unconfined test. It was decided to use a vacuum triaxial test, that is one where the lateral pressure is achieved by creating a negative pressure within the sample, rather than a positive pressure triaxial test, as it is less cumbersome to carry out.

The specimen size was determined by the maximum aggregate size. It has been found that a minimum ratio of test specimen diameter to maximum particle size of 4 to 1 should be observed (15). A ratio of height to diameter of 2 to 1 is usually employed in cylindrical compression testing. As the maximum particle size was to be 3 inches, a minimum specimen size of 12 inch diameter by 24 inch height was employed.

Classification and compaction tests were carried out on the material to be used in the triaxial investigation. The triaxial tests on the Winger pit gravel were restricted to six mixtures.

a) The original pit graded aggregate with plus 3 inch material removed.

b) As for (a) but with approximately 3.5 per cent minus #200 material removed.

c) As for (a) but with approximately 6 per cent minus #200 material removed.

d) The original pit graded aggregate, including oversized material, crushed to 2 inch maximum particle size.

e) As for (d) but crushed to 1½ inch maximum size.

f) As for (d) but crushed to 1 inch maximum size.

As failure occurred in the field at a moisture content greater than optimum, the triaxial tests on the above material were carried out at optimum moisture content, and repeated with the material compacted at a moisture content

somewhat higher than optimum.

This investigation, therefore, attempted to evaluate the relative merits of washing and crushing of the aggregate. An attempt was also made to compare the quality of aggregates by correlating the results obtained with the various methods of base course design in use in Canada and the United States today,

Various authors have reported varying degrees of success in improving characteristics of soils and soil aggregate mixtures using admixtures of portland cement, lime and lime fly-ash. The soils tested have ranged from fine grained medium plastic clay-silt-sand mixtures to relatively clean sands and gravels. The improvements reported were:

a) A reduction in the plasticity index of the soils (3) (17) (18) (19)

b) A drying effect upon the soils (17)

c) A greater stability of the soils in unconfined compression, triaxial compression, CBR, and other strength tests (3) (17) (18) (19) (20) (21) (22) (23)

d) Less susceptibility of the soil to shrinkage and expansion due to changes in moisture content (17) (18) (20)

e) A smaller loss during wet-dry, and freeze-thaw tests (18) (19) (20) (21) (22)

f) A much smaller strain at failure under stress (3) (20)

g) An increase in the optimum moisture content for compaction when lime and fly-ash was used, and a decrease in optimum moisture content when cement was used (21) (22)

Clark (3) noted that the plasticity of the fines of the Crawford gravel was affected not only by the quantity of cement or lime fly-ash employed, but also by the time of curing the mixture. Part B of the Current investigation was to determine the effect of time upon the Liquid and Plastic Limits and Plasticity Index of the fines when treated

with varying amounts of portland cement and of lime fly-ash. A ratio of 1 part lime to two parts fly-ash was used to conform with Clark's work.

In addition, triaxial shear tests were carried out to determine the effect upon the strength of large (12 inch diameter by 24 inches high) specimens of Crawford gravel, containing all sizes up to a maximum of 3 inches, due to the addition of a small amount of portland cement.

PART A

MECHANICAL STABILIZATION OF WINGER PIT GRAVEL, WHICH HAD AN EXCESS OF LOW PLASTIC FINES, FOR USE AS A HIGHWAY BASE COURSE

CHAPTER II

CLASSIFICATION AND ANALYSIS OF MATERIALS INVESTIGATED

The source of the gravel used in this part of the investigation was the Winger Pit (SW-14-30-1-W5) near Carstairs, Alberta. A visual examination of the native gravel, as well as grading and Atterberg Limit tests, showed that the material corresponded to the GF soil group of the Casagrande Airfield Classification System (1), and to an A-2-4 soil with a Group Index value of 0 as determined by the AASHO Classification System (2).

Table I shows the average results of the sieve analysis and Atterberg Limit tests carried out on some twenty samples throughout the pit by the Testing Laboratory of the Alberta Department of Highways.

TABLE I MECHANICAL ANALYSIS AND PLASTICITY TESTS - WINGER PIT

Oversize (+3")	2%
Sieve	**% Passing**
3"	100
1½"	75
3/4"	56
#4	36
#10	31.5
#40	26.2
#200	14.4

Atterberg Limits on - #40 Portion

Liquid Limit	23.7
Plastic Limit	15.5
Plasticity Index	8.2

It may be noted that all Atterberg Limits were carried out after the material had been allowed to soak 24 hours at a moisture content near the plastic limit.

As this investigation intended to determine any variation in strengths of the native gravel due to crushing to various maximum sizes, or to a reduction in the minus #200 portion of the gravel, six different mixtures were employed. The mixtures were obtained by separating the aggregate,by dry sieving,into ten size groups and re-combining to obtain the desired gradation. The mixtures which were to be crushed were first identically combined and then crushed to their respective maximum sizes. The results of the desired gradings and the actual gradings obtained, as determined from sieve analyses at the conclusion of triaxial testing, are shown in Table II.

TABLE II DESIRED AND ACTUAL GRADINGS OF AGGREGATE USED FOR TRIAXIAL TESTING

Percentage Passing Designated Sieve

Sieve No.	Mix #1 D.	Mix #1 A.	Mix #2 D.	Mix #2 A.	Mix #3 D.	Mix #3 A.	Mix #4 D.	Mix #4 A.	Mix #5 D.	Mix #5 A.	Mix #6 D.	Mix #6 A.
Oversize	-	-	-	-	-	-	2	-	2	-	2	-
3"	100	100	100	100	100	100	98	-	98	-	98	-
2"	-	-	-	-	-	-	-	100	-	100	-	-
1½"	75	73	75	76	75	77	73	95	73	99	73	100
1"	-	-	-	-	-	-	-	84	-	88	-	99
3/4"	56	56	56	57	56	58	55	69	55	73	55	87
#4	36	36	35	35	34	33	35	42	35	44	35	46
#10	31.5	33	29.5	30	27.5	28	31	38	31	41	31	41
#40	26.2	26	21.5	22	18.5	20	25.6	29	25.6	32	25.6	32
#200	14.4	15.0	10.0	11.4	7.0	9.2	14.1	17.3	14.1	18.5	14.1	19.1

The Atterberg Limits of the minus #40 sieve portion of the original aggregate sample were:

Liquid Limit	21.2
Plastic Limit	12.5
Plasticity Index	8.7

The specific gravities of the coarse and fine fractions of the Winger Gravel used in the triaxial shear experiments were as follows:

Specific Gravity of + #4 material = 2.71

Specific Gravity of - #4 material = 2.68

In the combination of 65% coarse, 35% fine, the average specific gravity of the mixture would be 2.70.

The data for the sieve analysis tests, summarized in Table II, and for the Atterberg Limits and Specific Gravity tests are contained in Appendix B.

The results of compaction tests run on the minus #4 sieve portion of mixtures number 1, 2 and 3 are shown in Table III. The results obtained were used in estimating the optimum moisture content to be used for each aggregate mixture. The minus #4 sieve portion for mixtures number 4, 5 and 6 were considered to have the same optimum moisture content as for mixture number 1, insofar as the original fines were concerned, and an optimum moisture content of 5% for the fines resulting from crushing.

TABLE III RESULTS OF COMPACTION TESTS ON WINGER MINUS #4 SIEVE MATERIAL

Material Tested	Test Type	Optimum Moisture Content	Maximum Dry Density
Mixture #1	½ Standard Proctor* (3 lifts, 13 blows)	11.5%	121.9 lbs./cu.ft.
Mixture #2	" "	10.7%	124.4 lbs./cu.ft.
Mixture #3	" "	10.7%	125.7 lbs./cu.ft.

(See Appendix B for data sheets)

The absorption of the coarse aggregate was found to be 1.8% from the specific gravity tests. Thus from the compaction tests, absorption of the coarse aggregate, and by arbitrarily choosing an optimum moisture content of 5% for the fines produced from crushing, the optimum molding water content was estimated for each mixture. A sample computation of the water content for Mixture #4 is given in Appendix A. The optimum molding water contents were found to be:

*One-half Standard Proctor compaction was used in order to correlate results with those obtained by Clark (3).

Mixture #1	5.3% water
Mixture #2	5.1% water
Mixture #3	5.0% Water
Mixture #4	5.4% water
Mixture #5	5.5% water
Mixture #6	5.6% water

The above figures are merely estimates, as, though the average compaction energy per unit volume was the same for the compaction tests as was used in forming the triaxial specimens, the following factors differed between the two tests:

a) the maximum particle size,

b) the ratio of maximum particle size to specimen diameter,

c) the ratio of specimen height to diameter,

d) the number and thicknesses of the layers used in forming the specimens,

e) the compaction hammers used,

f) the technique of compaction, i.e. With the compaction test, a constant number of blows per layer was employed, whereas in forming the triaxial specimens, the number of blows increased with each layer from 44 to 68 in an effort to effect a uniform final density throughout the sample.

In spite of these differences, it was felt that the values of molding water contents obtained above were reasonable, and in any case, were comparable in evaluating the strengths obtained with the various mixtures.

A second series of triaxial tests were run at a molding water content of approximately 1% above the optimum for each mixture, or at an

approximate average moisture content of 6.3 per cent. At this moisture content it was felt that the degree of saturation was close to the maximum obtainable by compacting the aggregate at a moisture content in excess of optimum, without producing an excessive loss of unit weight.

The computed degree of saturation for specimens compacted near optimum moisture content varied from 38 to 62%. The average degree of saturation was 48%, and 13 out of 18 specimens had a degree of saturation between 43 and 53%.

For specimens compacted over optimum moisture content, the computed degree of saturation varied from 46 to 83%. In this case the average degree of saturation was 70%. Out of 18 such specimens, 13 had a degree of saturation between 60 and 80%.

The computed values for degree of saturation given above are only approximate. Actual values would be somewhat higher than indicated due to the fact that actual volumes of specimens were less than the computed volumes. Specimen volumes were computed using the forming mold diameter which was larger than the actual specimen diameters due to the roughness of surface of the specimens.

CHAPTER III

APPARATUS AND PROCEDURES FOR TRIAXIAL TESTS

APPARATUS

The detailed plans of the vacuum triaxial forming mold, 12 in. diameter by 24 in. high, used in forming the specimens, are shown by Clark (3). The forming mold is illustrated in Figures 1 and 2 at the close of Chapter III.

A list of equipment used in conjunction with the vacuum triaxial testing programme follows.

(1) A Tinius Olsen 30,000 Kgm. capacity hydraulic compression testing machine was used for applying the load to all specimens.

(2) A stable steel compaction table of approximately the same height as the bed of the Tinius Olsen machine was used to support the specimens during compaction. The table was used, rather than compacting the specimens on the concrete floor, to facilitate the moving of the specimens (approximate weight with base plate and head, 325 lbs.) into the Tinius Olsen machine for testing.

(3) A vacuum source included a single stage vacuum pump, capable of exhausting nearly a full atmosphere, reservoir, a supply of air lines with quick coupling connectors,and a water trap to prevent moisture from entering the vacuum pump and reducing its effectiveness.

(4) A small heavy metal plaster boat and shovels were used when mixing water with the sample.

(5) A 1000 lb. capacity platform scale was used for determining the weight of sample used in forming each specimen.

(6) A 100 lb. capacity scale was used to weigh out the quantity of each size of aggregate to be used.

(7) A 21 Kgm. capacity solution balance and a large forced draft

oven were used to determine moisture contents of the samples.

(8) The triaxial specimen molding and testing equipment included a rubber lined aluminum split forming mold, top plate, base plate, compaction hammer (Marshall hammer* with 12 ins. added to the fall), strain dial of 3 in. travel in 0.001 in. increments, and a circumference gauge. The circumference gauge consisted of a steel tape, graduated in increments of 1/32 in., mounted at mid-height around the circumference of the specimen on small plastic rollers. The gauge was held taut by an elastic band which allowed the gauge to distend with the bulging of the specimen during testing.Figures 3 and 4 show the circumference gauge in place immediately preceeding and following a test respectively.

PROCEDURE

The procedure followed in the various triaxial tests was:

(1) The native gravel was split into ten size ranges by dry sieving after the gravel had been subjected to 50 revolutions in the Los Angeles abrasion machine. No degradation of the gravel was noted, but the abrasion was sufficient to partially clean the sand and gravel particles of their coating of clay and silt and thus a better separation of the gravel into the various sizes was possible.

(2) Batches of 240 lbs. were made up for each of the aggregate mixtures required, taking into account in each weight of aggregate size used, the residual sizes adhering to the aggregate size, and the hygroscopic moisture content of each size in question. This was accomplished by carrying out a washed sieve analysis and a moisture content determination of air dried material on each of the aggregate sizes prior to combination of the aggregate. The 240 lb. batches were made up as follows in order to approximate the required gradation.

*A standard Marshall hammer consists of a 10 lb. sliding weight falling 18 inches onto a 3 7/8 inch diameter face.

MIXTURE NUMBER	WEIGHT OF SIZES IN POUNDS *			
	1	2	3	4, 5 & 6
+3 in.	-	-	-	4.8
-3 in. + 2 in.	36.0	36.0	36.0	35.3
-2 in. + 1½ in.	24.3	24.1	24.1	23.8
-1½ in. + 3/4 in.	45.6	45.5	45.5	44.8
-3/4 in. + 3/8 in.	30.1	31.3	35.2	29.5
-3/8 in. + #4	26.4	28.1	26.4	25.8
-#4 + #10	7.8	10.3	14.3	7.6
-#10 + #40	30.2	34.6	28.7	29.6
-#40 + #200	29.8	31.7	31.0	29.2
-200	11.7	-	-	11.5
TOTAL	241.9	241.6	241.2	241.9

The batches for mixtures 4, 5 and 6 were then crushed to their respective maximum sizes of 2 inches, 1½ inches and 1 inch.

(3) Samples of 30 lbs. each were then made up of minus #4 material for determining the maximum density and optimum moisture content for each of the mixtures. The batches for the compaction tests were made up in a similar fashion to the procedure used in determining the weight of each size as described in (2) above. Mixtures numbered 4, 5 and 6 were considered to have the same optimum moisture for the per cent passing the #4 sieve as had mixture number 1.

(4) The optimum moisture content of a specimen was then computed, and, knowing the hygroscopic moisture content of the specimen, the amount of water to be mixed with the aggregate was computed.

*The weights here are batching weights and do not refer to actual grain size distribution. For actual grain size distribution after Triaxial testing see Table II, Chapter II

(5) The aggregate batch was then placed in the metal plaster boat, mixed dry for approximately 2 minutes, and then the water was added slowly while mixing continued for an additional 5 minutes. All mixing was done by hand with shovels, and was continued until a uniform colour had been achieved. The sample was then covered with two layers of damp jute sacking to retard evaporation and the weight of moist sample plus boat was obtained and recorded.

(6) Prior to mixing the sample, the membrane was attached to the base plate which rested on the compaction table, the mold carefully placed on the base and bolted, and the membrane was stretched over the top of the mold and a vacuum applied between the mold and membrane. (See Figure 2). The effect of the vacuum between the mold and membrane was to hold the membrane snugly against the interior surface of the rubber lined mold during compaction of the specimen.

(7) The specimen was then compacted in the mold in seven equal layers, using the modified Marshall hammer. The number of blows on each layer was increased by 4 blows per layer starting with 44 blows on the first layer and ending with 68 blows on the last layer. This was done in order that a more uniform density throughout the specimen would be effected than would have been obtained by using 56 blows per layer. The total compactive energy used was thus 9,800 ft. lbs. or approximately 6,125 ft. lbs. per cubic foot.* Special care was used when compacting the top layer to insure that a reasonably smooth plane surface had been formed when compaction was complete. This was difficult to achieve when the samples were compacted over optimum moisture content.

(8) Any small depressions in the top surface of the specimen were filled with fines, which were tamped carefully into place. A thin layer of

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* This was the same compactive effort used by Clark (3).

20-30 Ottawa sand, approximately 1/16 to 1/8 inch thick was spread on the top surface of the specimen to provide as smooth a bearing surface for the top plate as possible. The top plate was then carefully lowered into place on the top of the specimen and rotated slightly under pressure to seat it. The membrane was then drawn up and over this plate and attached to it using long rubber strips.

(9) The remainder of the sample and the boat were then weighed and recorded to determine the weight of moist sample used in forming the specimen.

(10) The leads to the vacuum reservoir were then coupled to the top and bottom plates and a vacuum of 0.9 Kgm./ sq. cm. was obtained in the reservoir with the vacuum pump. The specimen was evacuated for approximately 5 minutes and then the forming mold was unbolted and carefully removed from around the specimen. Leaks in the membrane were located and patched with membrane rubber and rubber cement.

(11) When all leaks in the membrane had been located and patched, as evidenced by no drop in reservoir vacuum with the pump turned off, the specimen was eased from the compaction table onto the bed of the compression testing machine where it was carefully centred. The specimen was moved by pushing on the base plate so as not to disturb the specimen.

(12) The length of the specimen was measured at four points around the circumference of the specimen and the result averaged and recorded. The hydraulic testing machine was started, the table of the machine "floated" and the machine was zeroed for the range of loading to be used. The self-levelling head of the machine was brought down until contact was made with the top plate of the specimen. The strain dial indicator was then placed in position and an initial reading of the indicator was taken. The specimen

was then ready for testing.(See Figure 3.)

(13) Loading of the specimens was carried out at a rate of 100 Kgm. per minute (3% to 7% of the total load at failure for all specimens tested). The testing machine was not designed to be used for constant strain, thus a constant rate of loading was used instead. As all mixtures were subjected to this constant rate of loading, it was felt that the results obtained would be qualitatively, if not absolutely quantitatively, correct.

(14) Periodic simultaneous readings of load and strain were made throughout the test until failure had been reached. Failure was deemed to have been reached when a large strain occurred at the same, or a reduced load.

(15) When failure had occurred, the final strain reading was obtained and the load removed from the specimen. The vacuum leads were removed, after the specimen had been moved back onto the compaction table, and the membrane and top plate were removed. In all cases the specimen stood erect after removing the membrane.

(16) The specimen was then dumped back into the plaster boat, mixed slightly and a moisture content sample obtained.

(17) A small amount of water (100 cc.) was then mixed into the aggregate to offset evaporation, the lumps of aggregate mixture thoroughly broken down, and the above procedure repeated twice using vacuums within the specimens of 0.60 and 0.30 Kgm./sq.cm. respectively.

(18) At the completion of the three tests on one mixture of aggregate, the moist aggregate was placed in metal drums, the drums were covered and placed in the moist room overnight to be used the following day when three further tests, at the same lateral pressures but with increased moisture content, were performed. When it was not possible to carry out these tests the following day, a new moisture content of the material was obtained before proceeding.

(19) The following day, after the moisture content samples had been dried, weighed and cooled, the water lost by each sample was replaced, the samples mixed back into the aggregate mixture and additional water added to the mixture to increase the moisture content to the desired higher moisture content.

This procedure, it is realized, was not ideal. A new air dry sample should have been used for all six tests on one mixture. However, this was not possible as sieving, crushing and handling equipment, storage space and time were all limited. As it was, it was necessary to prepare over a ton of Winger aggregate for these tests, and, if a new sample had been used to form each specimen, a minimum of 5 tons of material would have been needed.

(20) When the mixture had been prepared at the higher moisture content, the above procedure, steps (5) to (17) were then repeated for three tests having lateral pressures of 0.30, 0.60 and 0.90 Kgm./sq.cm. The following exceptions in the case of the specimens with high moisture contents may be noted:

a) As difficulty was experienced in obtaining a vacuum throughout the sample, "dressmakers" felt was cemented to the inside surface of the membrane. This felt, approximately 0.04 inches thick, reduced the diameter of the specimen slightly but provided a free draining region between the membrane and the specimen and permitted the setting up of the vacuum throughout the specimen. Again the required vacuum was checked on the gauge, for a minimum 30 minutes before testing commenced, to insure that there was no reduction in vacuum.

b) As failure stress was not obvious with the wet specimens, due to extreme bulging which permitted increasingly higher loads, a circumference gauge was used to determine the area of the specimen at each increment of load. An initial reading of this gauge was obtained before loading commenced and readings were obtained simultaneously with those of load and strain. Loading was continued until the strain had reached the limit of the 3 inch dial indicator, at which time the load and circumference gauge readings were noted. In a majority of the cases, the maximum deviator stress, as computed using the area determined from circumference gauge readings, was obtained at a load somewhat lower than the maximum load on the wet specimen. Figures 3 and 4 show the circumference gauge in place before and after testing such a specimen.

FIGURE NO. I

DETAILS OF TRIAXIAL SPECIMEN FORMING MOLD

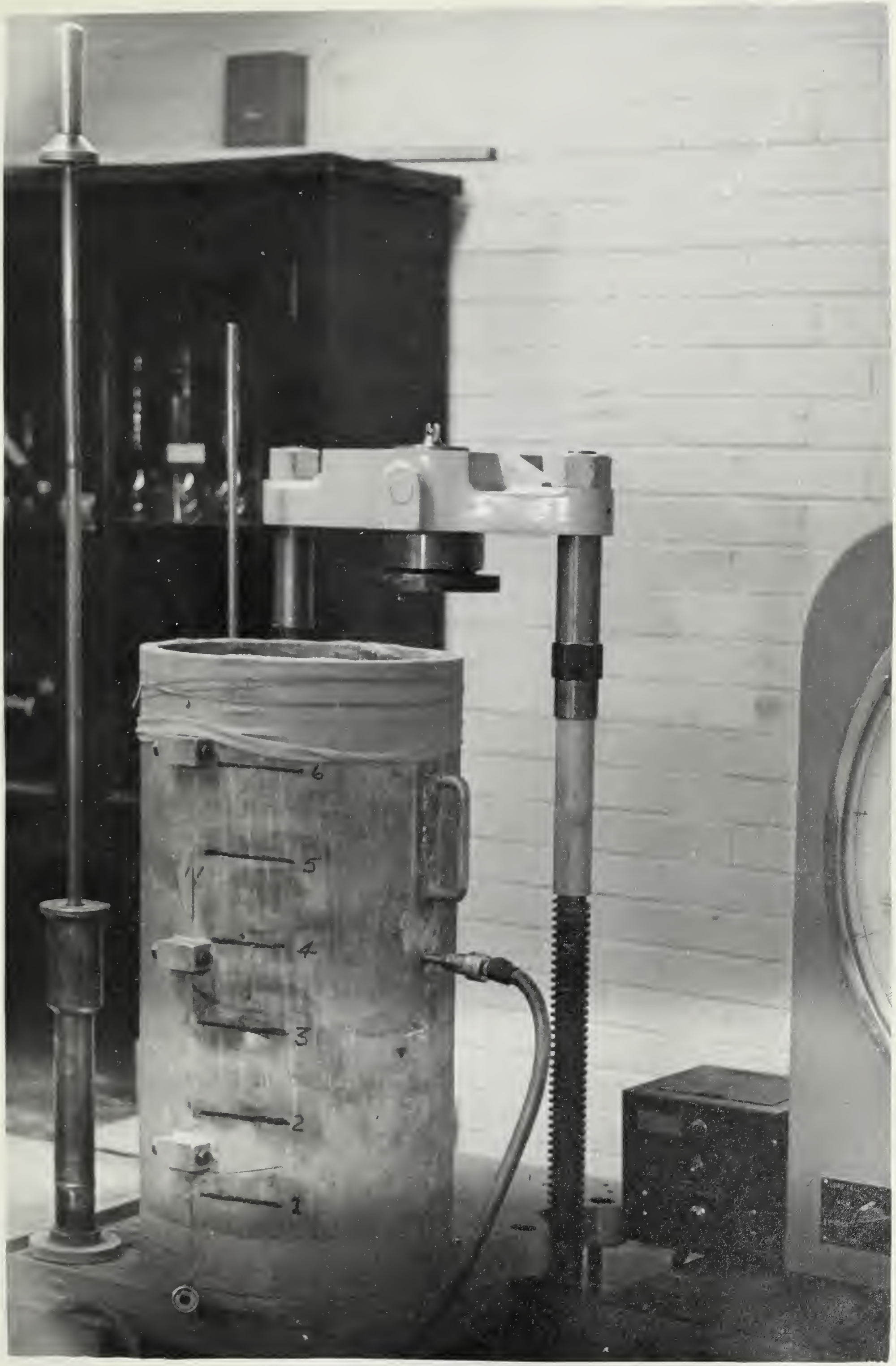


FIGURE NO. 2
FORMING MOLD ASSEMBLED

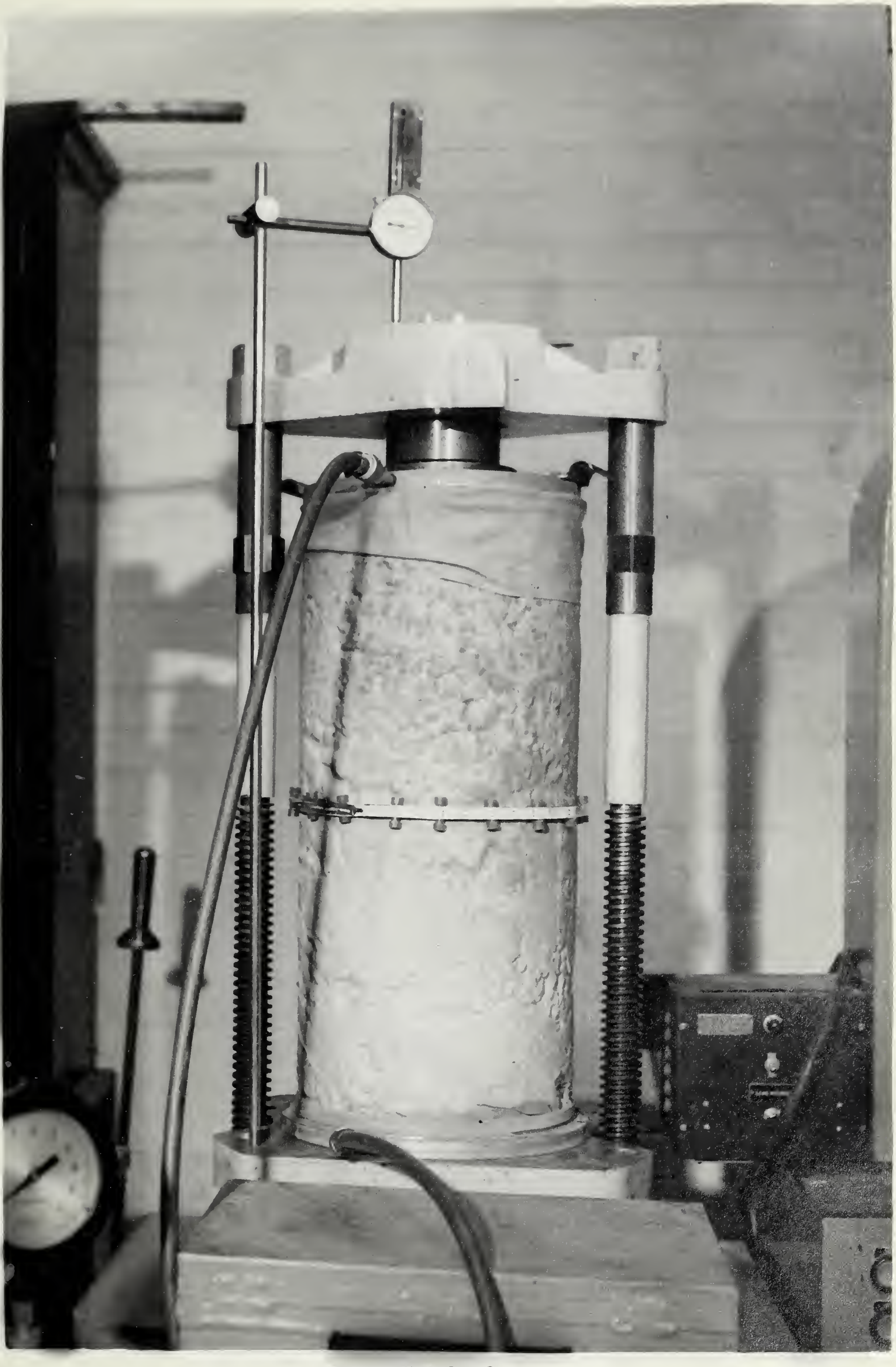


FIGURE NO. 3
SPECIMEN BEFORE TESTING

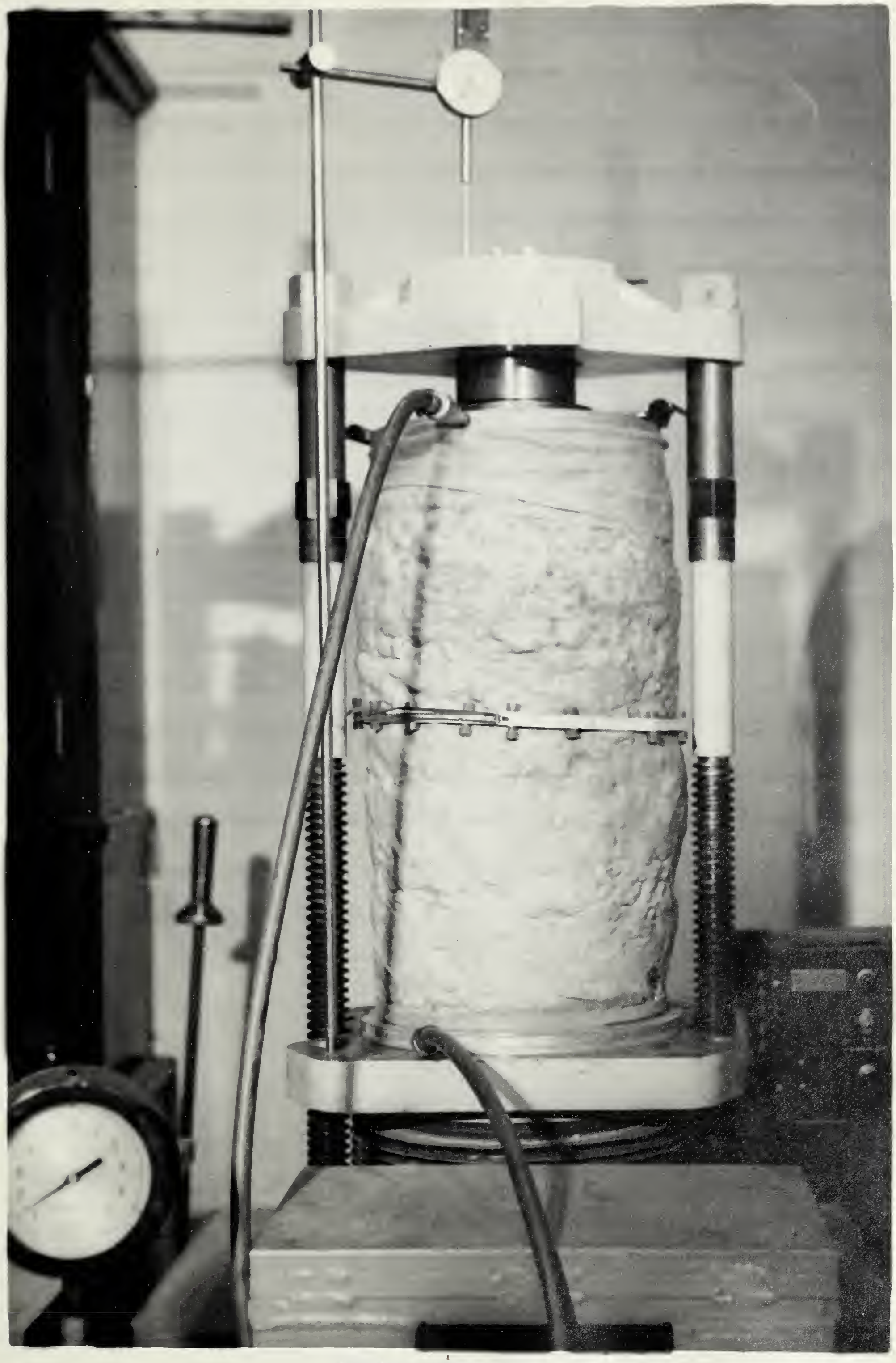


FIGURE NO. 4

SPECIMEN AFTER COMPLETION OF LOADING

CHAPTER IV

TRIAXIAL TESTING PROGRAMME RESULTS

The results of all vacuum triaxial tests carried out on Winger gravel are shown in tabular form in Table IV A to Table IV F inclusive, depending upon the aggregate mixture used. The data sheets for all triaxial tests on Winger gravel are included in Appendix B.

In addition to the above, the results of the testing programme are shown in other forms. Figures 5A to 5F inclusive show Mohr stress circles at failure and rupture lines for the six mixtures of aggregate both when compacted near optimum moisture and when compacted at approximately 6.3% moisture content. Figures 6 to 11 inclusive show the stress strain characteristics of each mixture when compacted near optimum moisture content and over optimum moisture content.

TABLE IV A

RESULTS OF TRIAXIAL TESTS OF WINGER GRAVEL - MIXTURE NO. 1

(3" native pit-run gravel)

Moist Unit Weight	Dry Unit Weight	Moisture* Content	Lateral Pressure	Deviator Stress at Failure	Strain at Failure	Cohesion	Angle of Internal Friction
lbs./cu.ft.	lbs./cu.ft.	%	Kgm./sq.cm.	Kgm./sq.cm.	%	Kgm./sq.cm.	degrees
139.6	132.7	5.2	0.30	1.96	2.14		
140.3	133.4	5.2	0.60	2.94	3.30		
142.3	135.3	5.2	0.90	3.73	3.47	0.4	34
141.9	133.2	6.5	0.30	1.73	6.0		
142.0	133.3	6.5	0.60	2.62	9.5		
146.3	137.4	6.5	0.90	3.00	9.6	0.4	30

* Moisture contents shown are averages of moisture contents of three consecutive test specimens re-using the same sample.

TABLE IV B

RESULTS OF TRIAXIAL TESTS OF WINGER GRAVEL -- MIXTURE NO. 2

(3" native gravel with 3.6% minus #200 removed)

Moist Unit Weight	Dry Unit Weight	Moisture Content	Lateral Pressure	Deviator Stress at Failure	Strain at Failure	Cohesion	Angle of Internal Friction
lbs./cu.ft.	lbs./cu.ft.	%	Kgm./sq.cm.	Kgm./sq.cm.	%	Kgm./sq.cm.	degrees
136.5	130.5	4.6	0.30	2.16	1.56		
138.1	132.0	4.6	0.60	3.52	1.69		
138.4	132.3	4.6	0.90	4.54	2.50	0.25	41.5
142.0	134.1	5.9	0.30	1.78	4.5		
142.7	134.9	5.9	0.60	2.62	4.5		
145.0	137.0	5.9	0.90	3.25	6.0	0.25	35

TABLE IV C

RESULTS OF TRIAXIAL TESTS OF WINGER GRAVEL - MIXTURE NO. 3

(3" native gravel with 5.8% minus #200 removed)

Moist Unit Weight	Dry Unit Weight	Moisture Content	Lateral Pressure	Deviator Stress at Failure	Strain at Failure	Cohesion	Angle of Internal Friction
lbs./cu.ft.	lbs./cu.ft.	%	Kgm./sq.cm.	Kgm./sq.cm.	%	Kgm./sq.cm.	degrees
141.2	135.0	4.8	0.30	1.88	1.64		
139.8	133.5	4.8	0.65	3.50	2.33		
145.7	139.1	4.8	0.90	4.28	2.61	0.2	41.5
145.7	136.9	6.5	0.30	1.70	6.0		
146.9	138.0	6.5	0.60	2.50	12		
147.4	138.5	6.5	0.90	2.80	11	0.2	37

TABLE IV D

RESULTS OF TRIAXIAL TESTS OF WINGER GRAVEL - MIXTURE NO. 4

(3" native gravel crushed to 2 in. maximum)

Moist Unit Weight	Dry Unit Weight	Moisture Content	Lateral Pressure	Deviator Stress at Failure	Strain at Failure	Cohesion	Angle of Internal Friction
lbs./cu.ft.	lbs./cu.ft.	%	Kgm./sq.cm.	Kgm./sq.cm.	%	Kgm./sq.cm.	degrees
135.3	128.4	5.4	0.30	2.08	2.96		
134.0	127.0	5.4	0.60	3.13	3.83		
137.2	130.1	5.4	0.90	4.11	5.94	0.25	39.5
131.2	123.7	6.1	0.30	1.74	3.25		
132.2	124.6	6.1	0.60	2.58	5.5		
137.2	129.3	6.1	0.90	3.53	7.0	0.25	36

TABLE IV E

RESULTS OF TRIAXIAL TESTS OF WINGER GRAVEL - MIXTURE NO. 5

(3" native gravel crushed to 1½" maximum)

Moist Unit Weight	Dry Unit Weight	Moisture Content	Lateral Pressure	Deviator Stress at Failure	Strain at Failure	Cohesion	Angle of Internal Friction
lbs./cu.ft.	lbs./cu.ft.	%	Kgm./sq.cm.	Kgm./sq.cm.	%	Kgm./sq.cm.	degrees
137.7	130.9	5.2	0.30	2.01	3.18		
138.5	131.6	5.2	0.60	3.16	5.21		
129.5	123.1	5.2	0.90	4.57	4.49	0.15	43
144.2	135.5	6.4	0.30	1.68	7.5		
146.0	137.2	6.4	0.60	2.53	8.0		
145.7	136.8	6.4	0.90	3.54	9.5	0.15	38

TABLE IV F

RESULTS OF TRIAXIAL TESTS OF WINGER GRAVEL - MIXTURE NO. 6

(3" native gravel crushed to 1" maximum)

Moist Unit Weight	Dry Unit Weight	Moisture Content	Lateral Pressure	Deviator Stress at Failure	Strain at Failure	Cohesion	Angle of Internal Friction
lbs./cu.ft.	lbs./cu.ft.	%	Kgm./sq.cm.	Kgm./sq.cm.	%	Kgm./sq.cm.	degrees
131.0	124.5	5.2	0.30	1.95	4.44		
136.6	129.8	5.2	0.60	3.04	5.49		
131.9	125.2	5.2	0.90	3.58	9.73	0.15	41
146.4	137.6	6.5	0.30	1.86	8.5		
144.5	135.7	6.5	0.60	2.68	10.5		
148.0	139.0	6.5	0.90	2.80	12.2	0.25	35

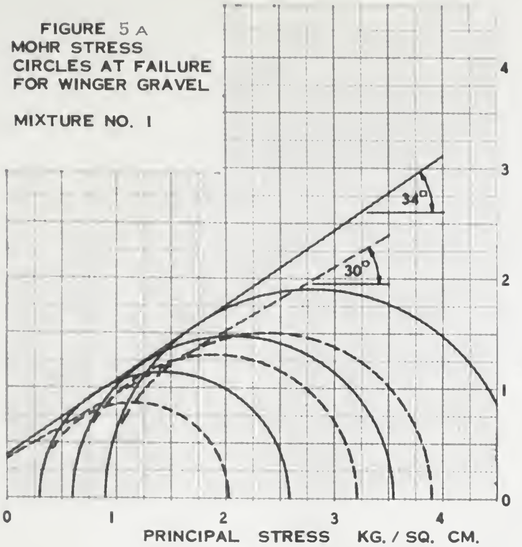


FIGURE 5 A
MOHR STRESS CIRCLES AT FAILURE FOR WINGER GRAVEL
MIXTURE NO. 1

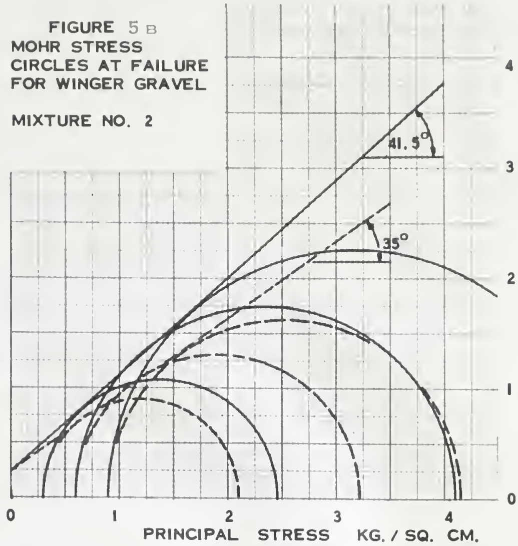


FIGURE 5 B
MOHR STRESS CIRCLES AT FAILURE FOR WINGER GRAVEL
MIXTURE NO. 2

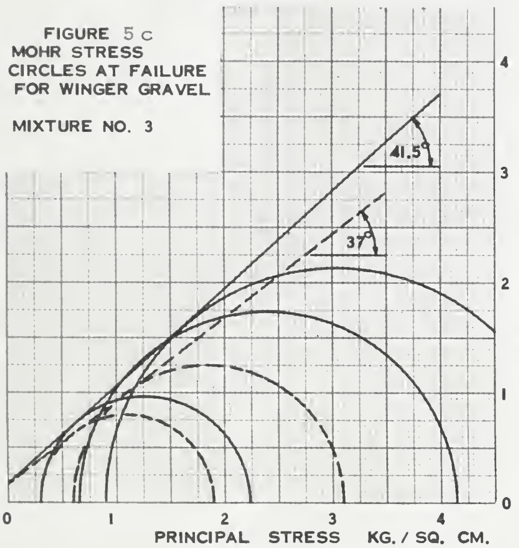


FIGURE 5 C
MOHR STRESS CIRCLES AT FAILURE FOR WINGER GRAVEL
MIXTURE NO. 3

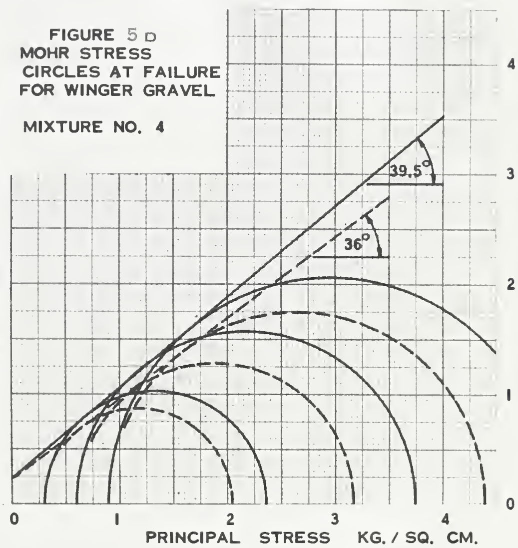


FIGURE 5 D
MOHR STRESS CIRCLES AT FAILURE FOR WINGER GRAVEL
MIXTURE NO. 4

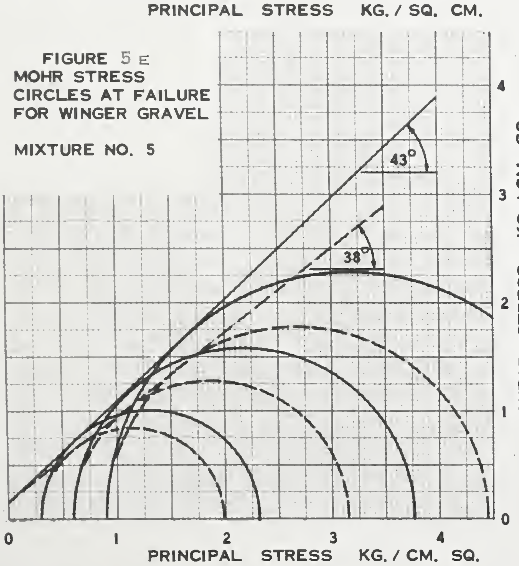


FIGURE 5 E
MOHR STRESS CIRCLES AT FAILURE FOR WINGER GRAVEL
MIXTURE NO. 5

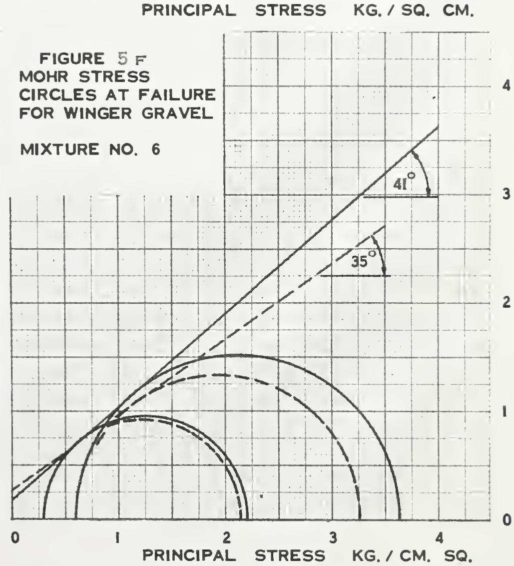
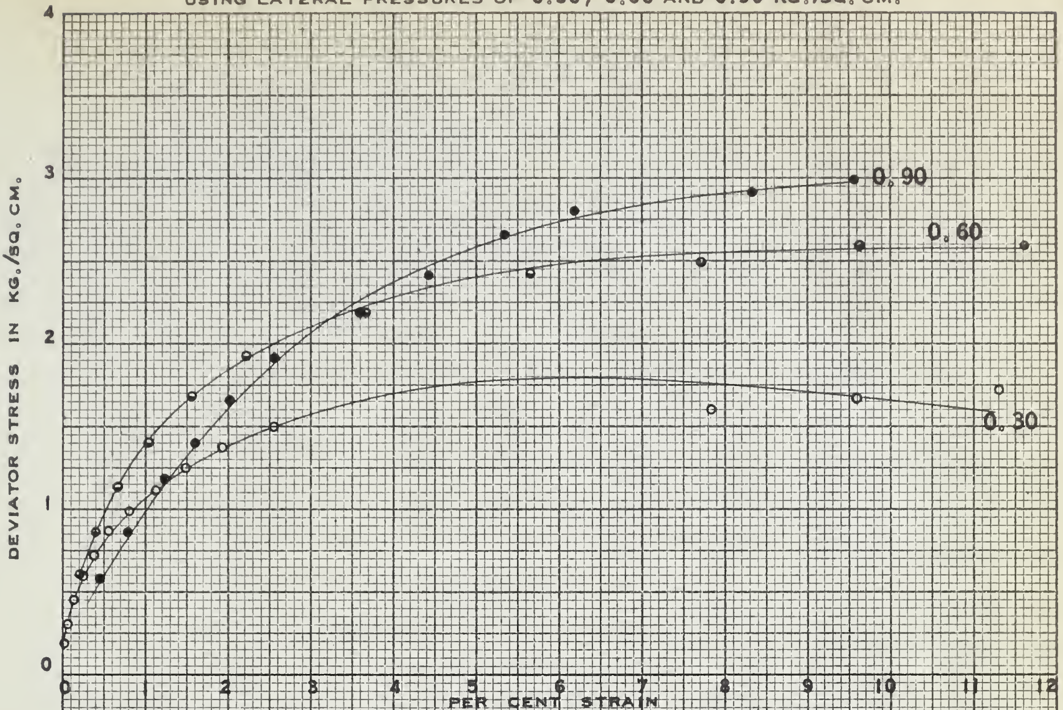


FIGURE 5 F
MOHR STRESS CIRCLES AT FAILURE FOR WINGER GRAVEL
MIXTURE NO. 6

NOTE - SOLID LINES INDICATE MATERIAL COMPACTED AT OPTIMUM MOISTURE CONTENT
DASHED LINES INDICATE MATERIAL COMPACTED AT APPROXIMATELY 6.3 PER CENT MOISTURE

FIGURE NO. 6 B

STRESS STRAIN RELATIONSHIPS FOR WINGER GRAVEL - MIXTURE NO. 1
COMPACTED AT A MOISTURE CONTENT 1.2 PER CENT OVER OPTIMUM
USING LATERAL PRESSURES OF 0.30, 0.60 AND 0.90 KG./SQ. CM.



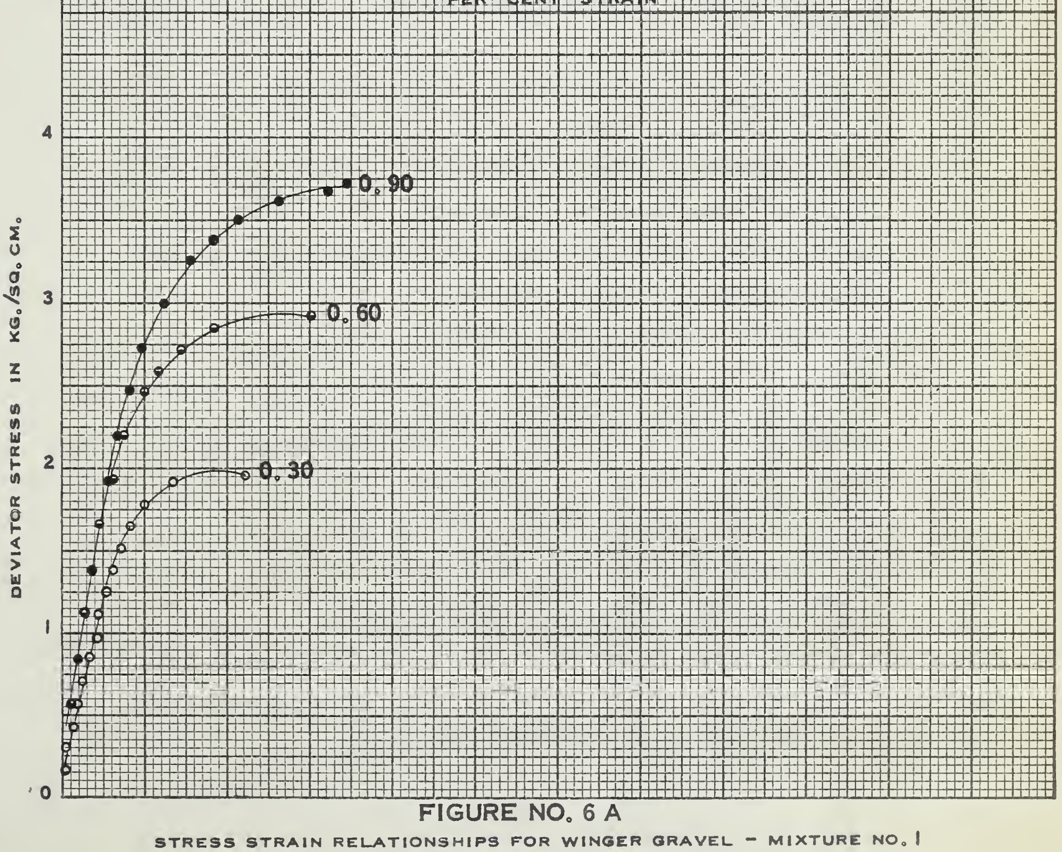
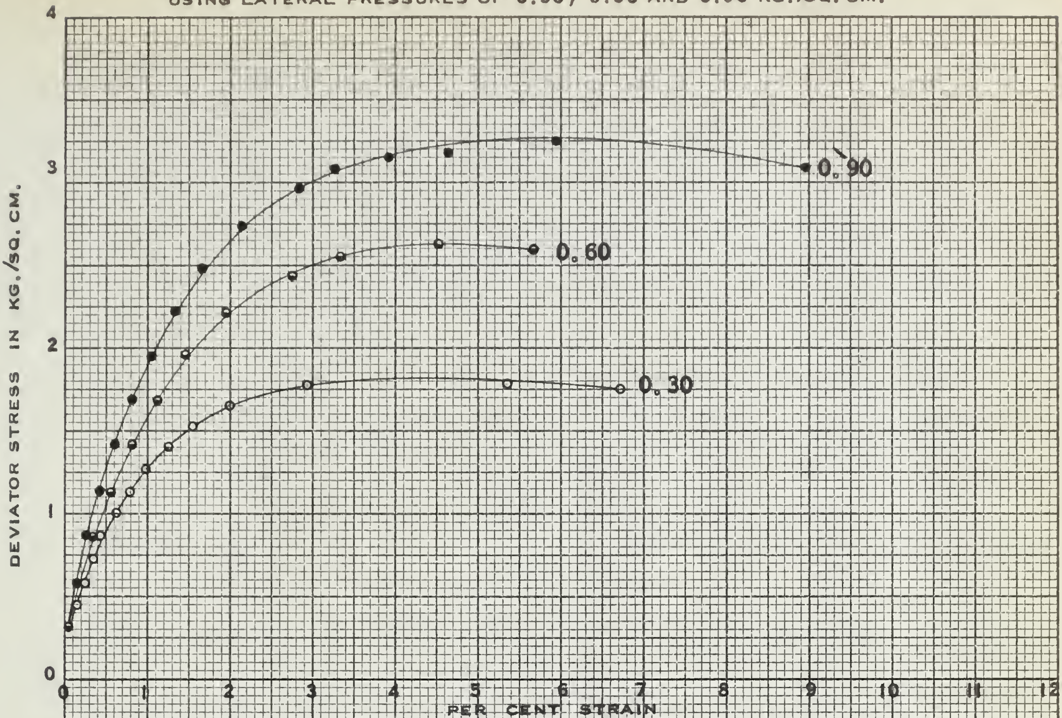


FIGURE NO. 6 A

STRESS STRAIN RELATIONSHIPS FOR WINGER GRAVEL - MIXTURE NO. 1
COMPACTED AT A MOISTURE CONTENT 0.1 PER CENT BELOW OPTIMUM
USING LATERAL PRESSURES OF 0.30, 0.60 AND 0.90 KG./SQ. CM.

FIGURE NO. 7 B

STRESS STRAIN RELATIONSHIPS FOR WINGER GRAVEL – MIXTURE NO. 2
COMPACTED AT A MOISTURE CONTENT 0.8 PER CENT ABOVE OPTIMUM
USING LATERAL PRESSURES OF 0.30, 0.60 AND 0.90 KG./SQ. CM.



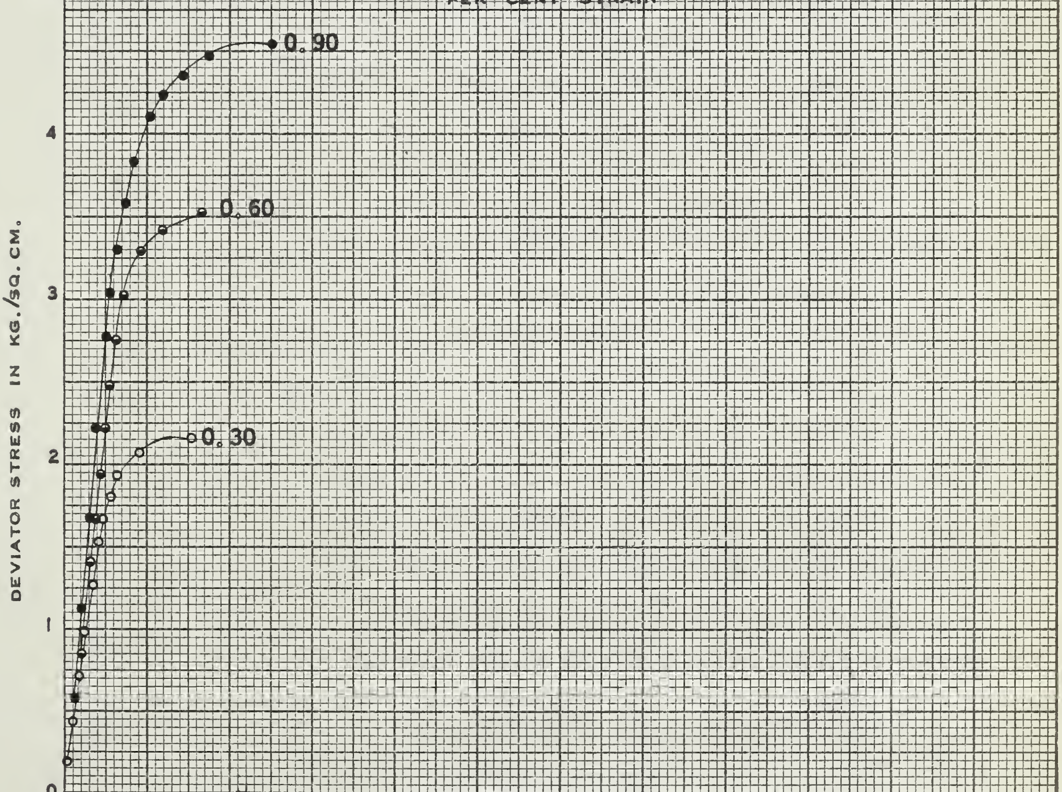
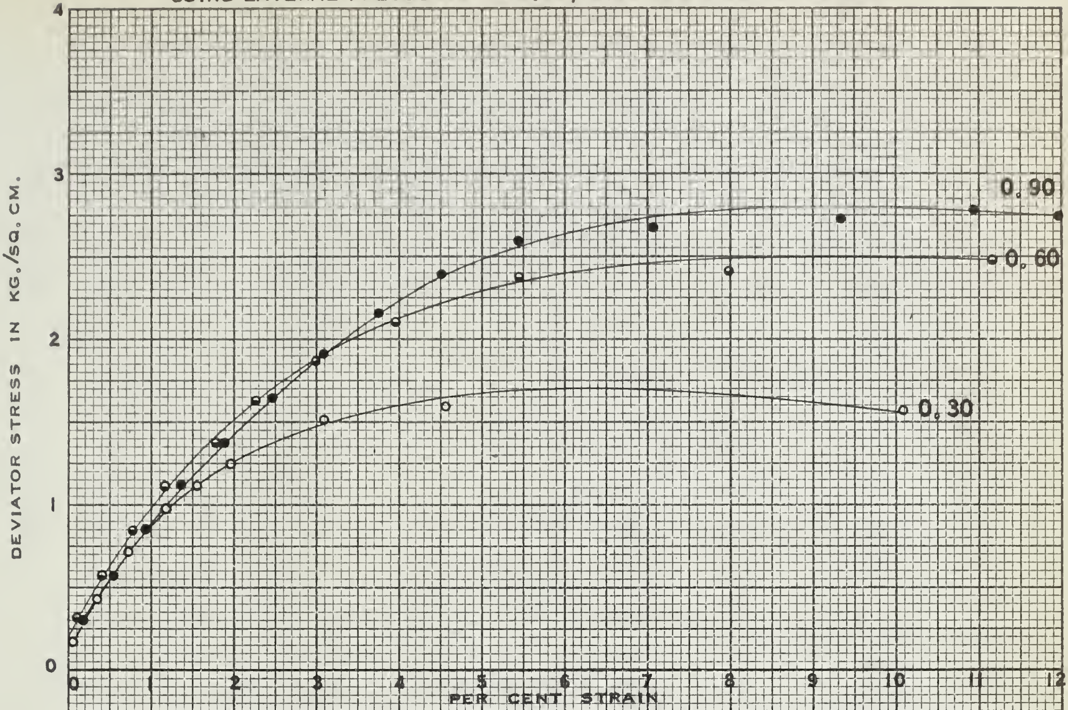


FIGURE NO. 7 A

STRESS STRAIN RELATIONSHIPS FOR WINGER GRAVEL – MIXTURE NO. 2
COMPACTED AT A MOISTURE CONTENT 0.5 PER CENT BELOW OPTIMUM
USING LATERAL PRESSURES OF 0.30, 0.60 AND 0.90 KG./SQ. CM.

FIGURE NO. 8 B

STRESS STRAIN RELATIONSHIPS FOR WINGER GRAVEL - MIXTURE NO. 3
COMPACTED AT A MOISTURE CONTENT 1.5 PER CENT ABOVE OPTIMUM
USING LATERAL PRESSURES OF 0.30, 0.60 AND 0.90 KG./SQ. CM.



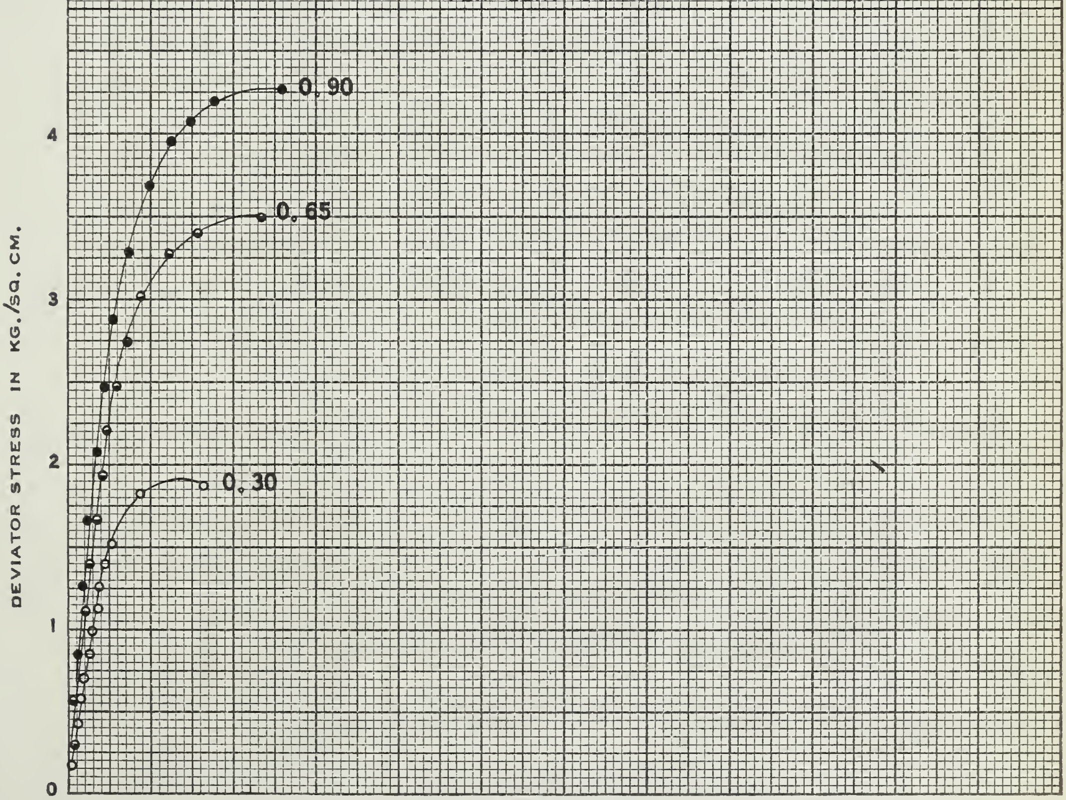
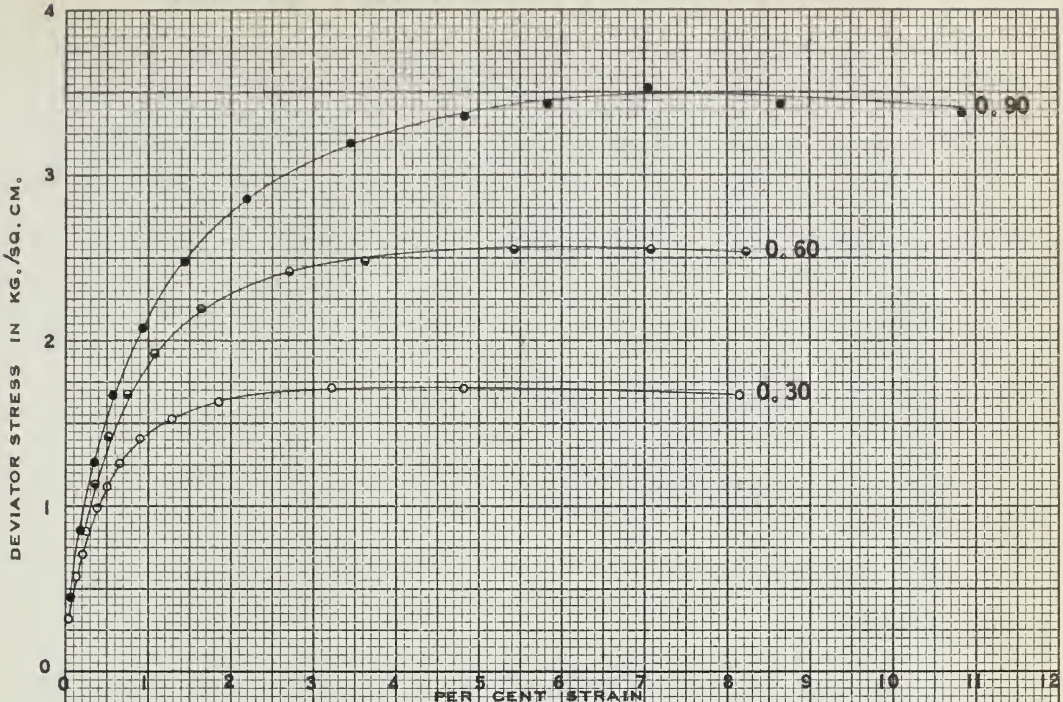


FIGURE NO. 8 A

STRESS STRAIN RELATIONSHIPS FOR WINGER GRAVEL - MIXTURE NO. 3
COMPACTED AT A MOISTURE CONTENT OF 0.2 PER CENT BELOW OPTIMUM
USING LATERAL PRESSURES OF 0.30, 0.65 AND 0.90 KG./SQ. CM.

FIGURE NO. 9 B

STRESS STRAIN RELATIONSHIPS FOR WINGER GRAVEL - MIXTURE NO. 4
COMPACTED AT A MOISTURE CONTENT 0.7 PER CENT ABOVE OPTIMUM
USING LATERAL PRESSURES OF 0.30, 0.60 AND 0.90 KG./SQ. CM.



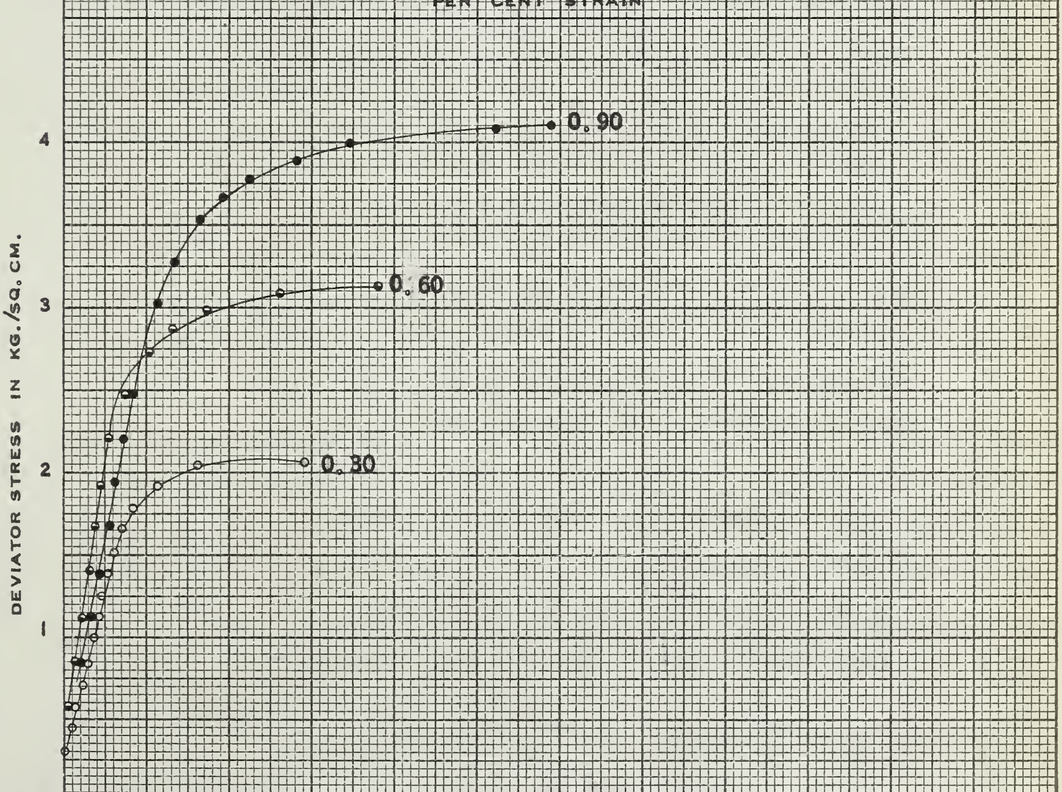
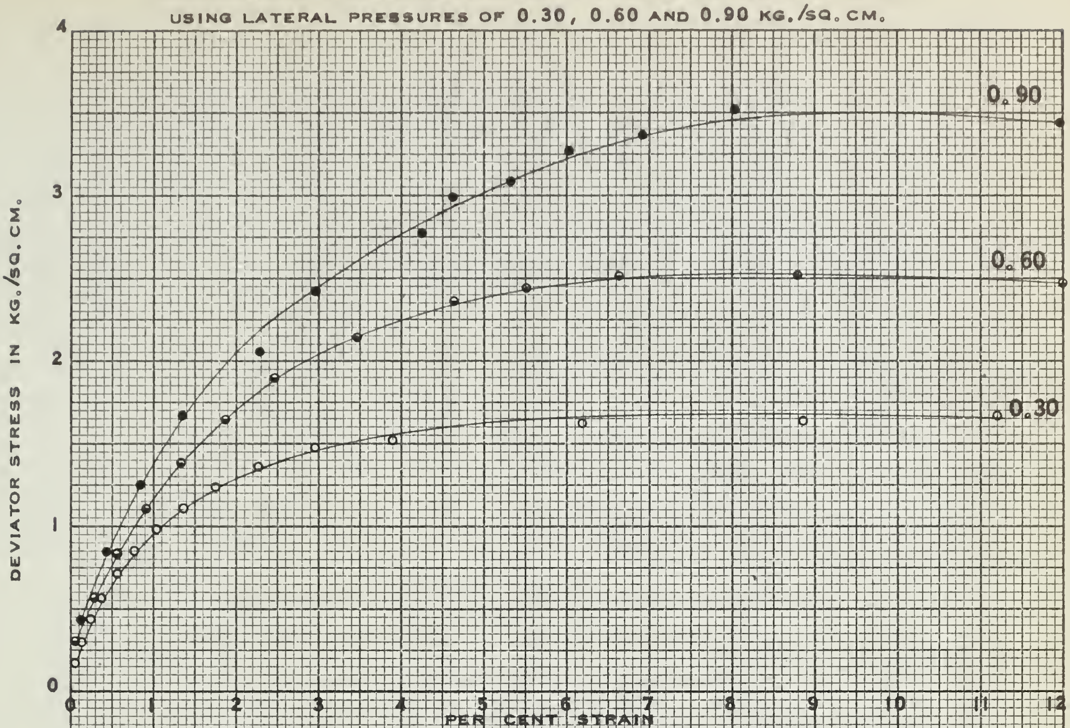


FIGURE NO. 9 A

STRESS STRAIN RELATIONSHIPS FOR WINGER GRAVEL - MIXTURE NO. 4
COMPACTED AT OPTIMUM MOISTURE CONTENT
USING LATERAL PRESSURES OF 0.30, 0.60 AND 0.90 KG./SQ. CM.

FIGURE NO. 10 B

STRESS STRAIN RELATIONSHIPS FOR WINGER GRAVEL - MIXTURE NO. 5
COMPACTED AT A MOISTURE CONTENT 0.9 PER CENT ABOVE OPTIMUM
USING LATERAL PRESSURES OF 0.30, 0.60 AND 0.90 KG./SQ. CM.



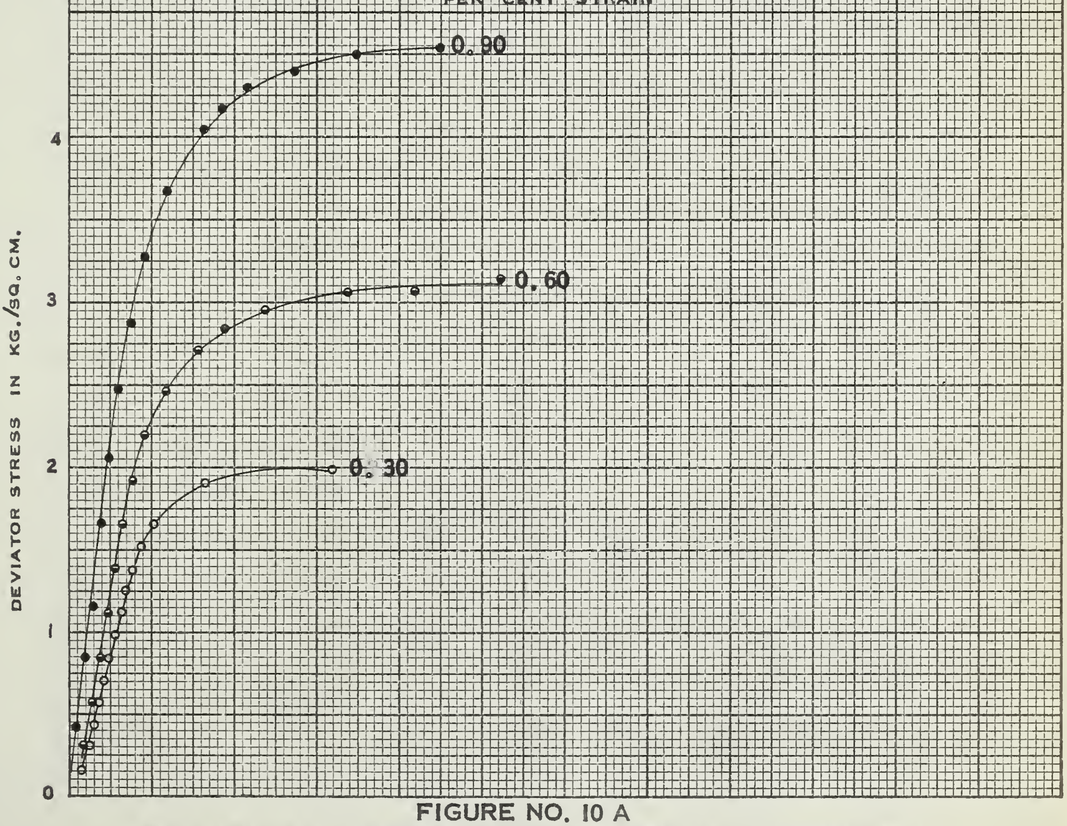
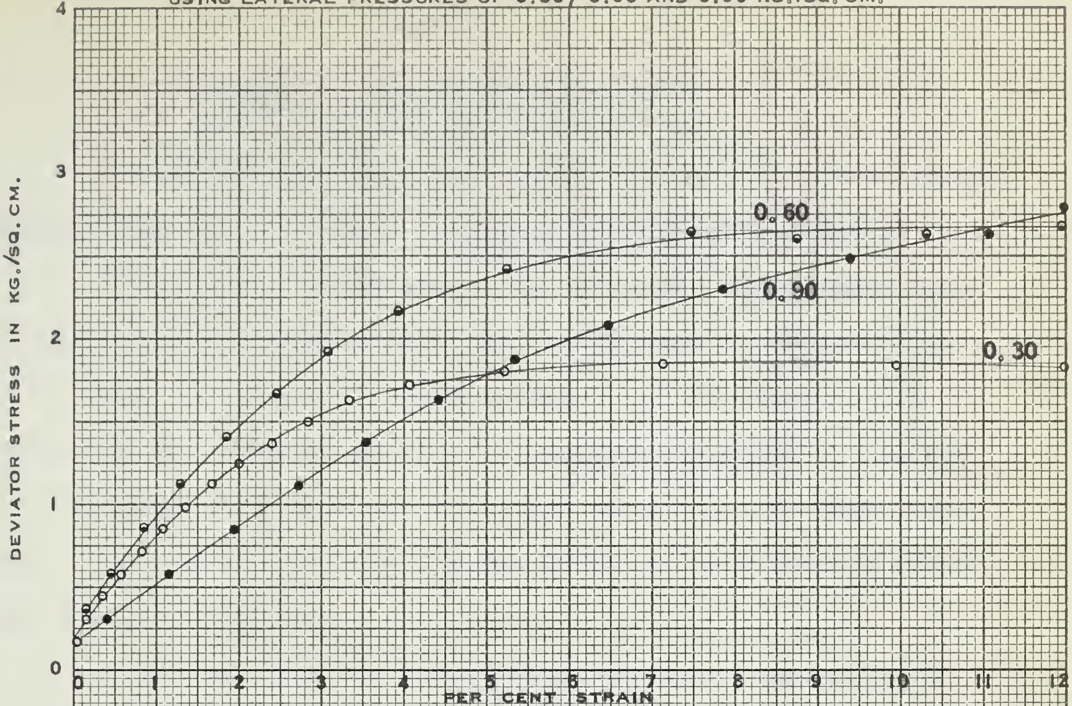


FIGURE NO. 10 A

STRESS STRAIN RELATIONSHIPS FOR WINGER GRAVEL - MIXTURE NO. 5
COMPACTED AT A MOISTURE CONTENT 0.3 PER CENT BELOW OPTIMUM
USING LATERAL PRESSURES OF 0.30, 0.60 AND 0.90 KG./SQ. CM.

FIGURE NO. II B

STRESS STRAIN RELATIONSHIPS FOR WINGER GRAVEL - MIXTURE NO. 6
COMPACTED AT A MOISTURE CONTENT 0.9 PER CENT ABOVE OPTIMUM
USING LATERAL PRESSURES OF 0.30, 0.60 AND 0.90 KG./SQ. CM.



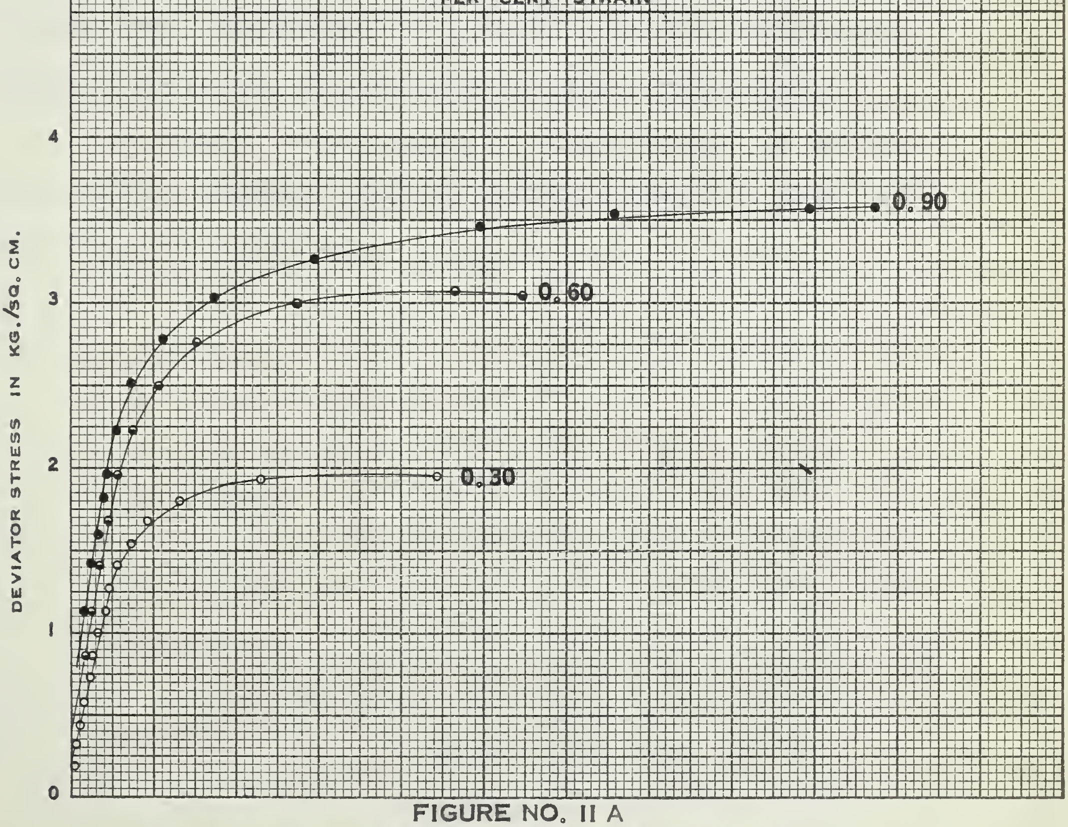


FIGURE NO. II A

STRESS STRAIN RELATIONSHIPS FOR WINGER GRAVEL - MIXTURE NO. 6
COMPACTED AT A MOISTURE CONTENT 0.4 PER CENT BELOW OPTIMUM
USING LATERAL PRESSURES OF 0.30, 0.60 AND 0.90 KG./SQ. CM.

CHAPTER V

CORRELATION OF TEST RESULTS WITH VARIOUS METHODS OF BASE COURSE DESIGN

Only three triaxial test methods are used today in the United States and Canada, to evaluate and design base and sub-base courses. (4)

California, in addition to the California Bearing Ratio Tests (C.B.R.), uses a modified triaxial test method known as the Hveem Stability Test. In this test, specimens four inches in diameter by 2½ inches high are tested triaxially. As the specimen height to diameter ratio of Hveem specimens is 5 to 8, high stresses from end effects would make it impossible to correlate the results of this investigation according to California methods.

Both the Texas and Kansas design methods use the results of triaxial tests. An attempt will be made hereunder to evaluate the results of the current investigation with these design methods.

A summary of the methods of evaluating base and sub-base course quality, currently in use in the United States, is shown in Tables VA and VB respectively.

TABLE V A

NUMBER OF STATES USING THE VARIOUS

MEANS OF EVALUATING BASE COURSE QUALITY

METHOD	NUMBER OF STATES
Gradation	19
Soil Constants (Limits)	16
Abrasion	11
Experience and Judgment	7
CBR or CBR modified	5
Hveem Stabilometer	4
Unnamed Stability	3
Hubbard-Field (for bituminous types)	2
Triaxial Compression	2
Miscellaneous	11

TABLE V B

NUMBER OF STATES USING THE VARIOUS

MEANS OF EVALUATING SUB-BASE COURSE QUALITY

METHOD	NUMBER OF STATES
Gradation	20
Soil Constants (Limits)	16
CBR or CBR modified	9
Judgment and Experience	4
Abrasion	3
Granular Materials Specified	3
Group Index	2
Triaxial Compression	2
Drainability	2
Miscellaneous	6

In addition to the above, N. W. McLeod, (5) (6) (7) (8) (9), advocates an in-place plate bearing test to evaluate various components of the pavement structure at their respective natural moisture contents. Further he states, ((9) item 4(c)) that it is difficult to compact angular aggregate to as high a density as the more rounded aggregates. Until a vibratory compactor, or other type of new equipment, can compact the angular, rough-surfaced crushed aggregates to as high a density as the more rounded aggregates, and until it can be shown that these relative density characteristics can be retained in service, "the supporting values per unit thickness of base courses made from pit-run and crushed-run gravels, crushed stone, and the various mechanically stabilized aggregates, must be considered essentially equal."

Thus, in the discussion below, an attempt is made to evaluate the results of this investigation using only the triaxial test methods as outlined by the Kansas and Texas State Highway Departments.

TEXAS METHOD (10) (11)

This method may be summarized as follows:

1: Specimens are formed in molds 6 in. diameter by 8 in. high at optimum moisture content.

2: The specimens are permitted to air dry overnight and then are oven dried at 140° for 8 hours.

3: The specimens are again allowed to stand overnight and then are allowed to absorb capillary moisture under a surcharge and lateral pressure both of 1 p.s.i. until equilibrium is reached.

4: The specimens are then tested triaxially under varying lateral pressures.

5: The rupture envelope thus obtained is compared with a chart

indicating various classes of subgrade and flexible base materials, for use in evaluating the thickness of cover material required for various wheel loads. See Figure 12.

Figure 12 illustrates the Texas Highway Department soil classifications obtained from triaxial tests carried out according to the Texas procedure. Rupture lines for mixtures number 1 and number 5, compacted above optimum moisture content, have been plotted on Figure 12 and both indicate a material borderline between Class 3 and Class 4.

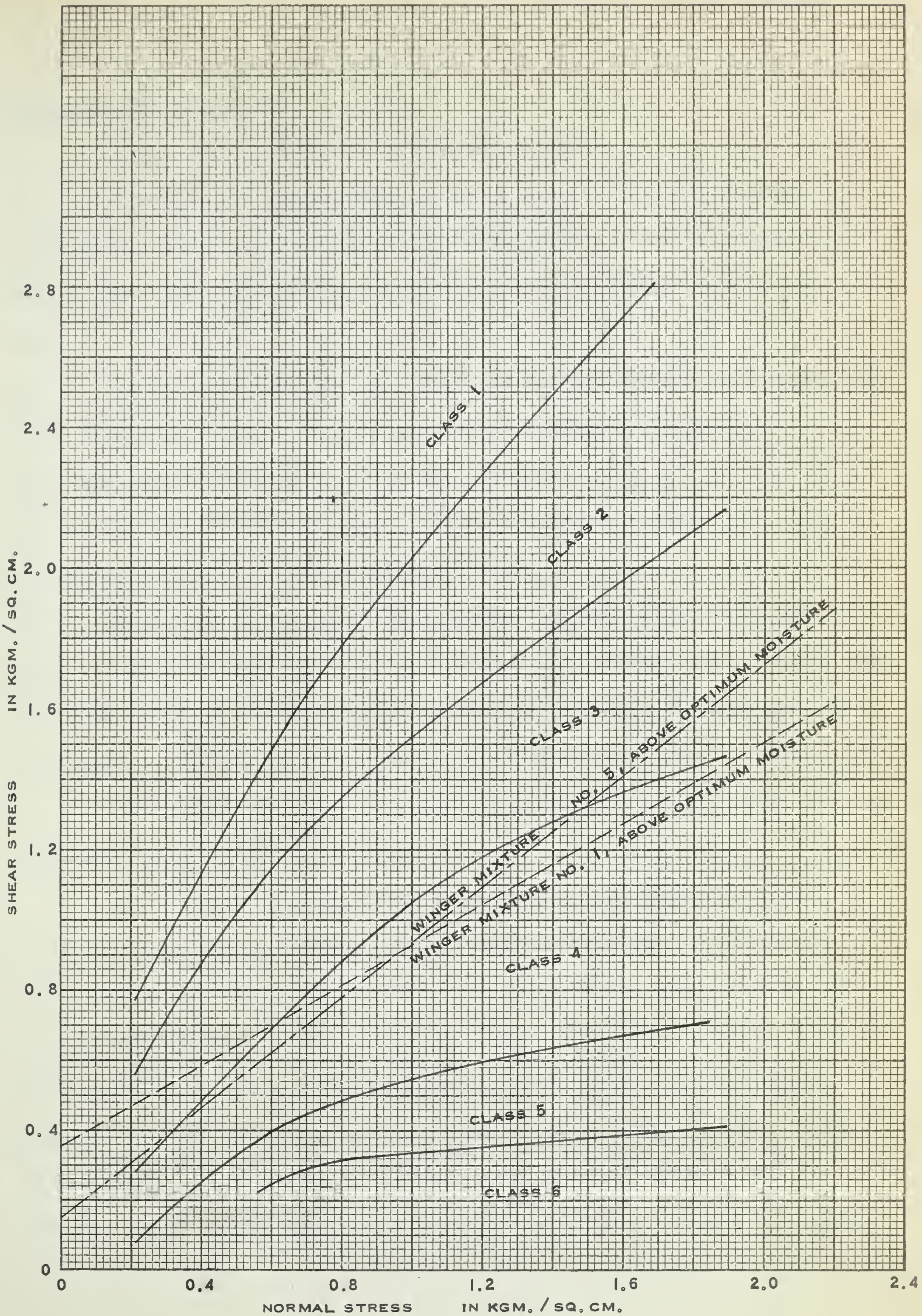
Triaxial test results on a free draining, crushed quarry rock were reported by McDowell (11) and Holtz and Gibbs (12). Holtz and Gibbs, using specimens with a height to diameter ratio of 2 to 1, as was used in the current investigation, found that the angle of internal friction of such an aggregate was 45 degrees, and that there was no cohesion. This would classify such a material as borderline between Classes 3 and 4 according to the Texas Classification. McDowell, using a similar crushed rock, (Lab. No. 49-14-R, pp 5, 9 and 15, (11)), reported test results obtained using the Texas procedure. This procedure, which specifies a specimen height to diameter ratio of 1 1/3 to 1, gave results indicating a Class 1 material.

It is therefore apparent that the results obtained using the two height to diameter ratios are not comparable. The specimens tested according to the Texas procedure, having a height to diameter ratio smaller than the generally accepted minimum of 2 to 1, gave a higher value for the angle of internal friction due to the deviator stresses being greatly influenced by the end restraint upon the specimens.

Thus, while rupture lines for mixtures number 1 and number 5, compacted above optimum moisture content, have been plotted on Figure 12, there is, in fact, no correlation between the rupture lines obtained in

FIGURE NO. 12

SOIL CLASSIFICATIONS - TEXAS METHOD OF BASE DESIGN



this investigation and those presented using the Texas triaxial method of design.

KANSAS METHOD (13) (14)

This method may be summarized as follows:

1: Specimens of subgrade are either cut from undisturbed samples or disturbed samples are obtained from compaction at saturation under a static load. The specimens are normally 2.8 inch diameter by 8 inches high.

2: Undisturbed subgrade specimens are tested in a triaxial apparatus under a lateral pressure of 20 p.s.i. after saturation by vacuum. Remolded subgrade specimens are allowed to moist cure, are saturated by vacuum, and then are tested under a lateral pressure of 20 p.s.i. The stress strain curve is obtained in each case.

3: Base course materials are formed at optimum moisture content in molds 5 inches in diameter by 14 inches high, are saturated by vacuum, and then are tested in a triaxial testing apparatus under a lateral pressure of 20 p.s.i. The stress strain curve is found for the base material.

4: The asphaltic surface course is assumed to have a minimum modulus of deformation of 15,000 p.s.i.

The modulus of deformation is defined as the deviator stress divided by the strain. In the case of asphaltic materials, a straight line relationship exists until failure is imminent and thus the modulus of deformation is the tangent modulus. This is also the case with clean well graded base course aggregates as specified by the Kansas Highway Department. The subgrade, however, usually has no straight line portion to the stress strain curve. Thus the secant modulus, which is the deviator stress at any strain, divided by that strain, is used for subgrade

soils and is not a constant value for any soil in a plastic state.

5: Graphical solutions from charts are then used to solve the equation:

$$T = \left[-\sqrt{\left(\frac{3Pmn}{2\pi CS}\right)^2 - a^2} \right] \left[\sqrt[3]{\frac{C}{C_P}} \right]$$

where T = thickness of asphaltic pavement required in inches.

Cp = modulus of deformation of pavement or surface course in p.s.i.

C = modulus of deformation of subgrade in p.s.i.

P = basic wheel load in lbs.

m = traffic coefficient based on volume of traffic.

n = saturation coefficient based on rainfall.

a = radius of area of tire contact corresponding to Pm.

S = permitted deflection of surface.

Kansas use a maximum value for S of 0.1 inch. The values for m and n for the highway where the Winger pit was used were found from gross loads allowable and from weather data to be I and 0.6 respectively.

The evaluation of the mixtures of Winger gravel was obtained from the stress strain curves for both optimum and over optimum moisture condition and a lateral pressure of 0.9 Kgm./sq.cm. (12.8 lbs./sq.in). This lateral pressure is the practical maximum obtainable using vacuum triaxial methods, and would not, in fact, give values of thickness of surfacing required according to the Kansas method where a lateral pressure of 20 lbs./sq.in. is used. It was considered, however, that the thickness values obtained might serve to produce a qualitative evaluation of the base material. The results obtained are as outlined in Table VI.

TABLE VI

ASPHALTIC PAVEMENT THICKNESS REQUIREMENTS ACCORDING TO THE KANSAS DESIGN METHODS

MIXTURE NO.	THICKNESS REQUIRED FOR BASE NEAR OPT. M.C.	THICKNESS REQUIRED FOR BASE OVER OPT. M.C.
1	2.0 inches	6.2 inches
2	0 inches	3.2 inches
3	0 inches	6.9 inches
4	1.6 inches	3.0 inches
5	0 inches	4.4 inches
6	2.3 inches	not evaluated

The thickness requirements shown in Table VI were computed according to the original Kansas design curves and traffic and saturation coefficients published in 1947, (14). The traffic and saturation coefficients were modified in 1953, (25), but values for required thickness using to the modified factors varied from the original by only plus or minus one inch. (See Figure 5, (25)). Thus the thickness requirements shown in Table VI are relatively, if not absolutely, correct according to the present Kansas design practice.

The major differences in thicknesses of pavement required as shown in Table VI are due to the variation in moisture content, in the most part, and to evaluating stress strain curves which may, or may not be absolutely correct. Small variations in these curves, even though the failure stresses and strains may be equal for each curve result in large changes in the thickness of surface course required. As the shapes of

the experimental stress strain curves are dependent upon such factors as density and moisture content of the sample, proper knitting and alignment of the particles in the sample, and accurate seating of the loading head and strain dial, it is felt that a proper evaluation of the aggregate mixtures cannot be made using the Kansas method.

The variations in the shapes of experimental stress strain curves may be noted in Figures 6 to 11.

Sample computations of pavement thickness requirements, using the Kansas method, are shown in Appendix A.

It would appear, therefore, that no valid correlation can be established between the triaxial tests as carried out in this investigation and the triaxial tests as performed by the Kansas and Texas State Highway Departments. It is thus not possible to correlate the results of this investigation with base course design procedures in present use in Canada or the U.S.A.

CHAPTER VI

DISCUSSION AND CONCLUSIONS

The results obtained in this part of the investigation indicate that the strength characteristics of a native gravel, which has an excess of low plastic fines, can be improved in two ways, namely,

1) By crushing to an optimum maximum particle size.
2) By washing the aggregate to remove a portion of the minus #200 sieve material.

It may be noted from Figure 5 that the angle of internal friction for mixtures 2 to 6 inclusive, in a wet condition, were all higher then that for the original material, mixture No. 1, compacted at optimum moisture content. It may also be noted that the value for cohesion varied only between 0.15 and 0.40 kgm. / sq. cm. As these values are within the degree of accuracy of the test used, it may be assumed that crushing or removing fines from this material had little effect upon the value for cohesion.

An assumption might be made that as the angle of internal friction of the original material at optimum moisture content, 34 degrees, was sufficiently high to prevent failure under the imposed highway construction loads, and as all other mixtures in a wet condition had angles of internal friction greater than 34 degrees, any of these other mixtures in a wet condition would have performed satisfactorily under the loads. This assumption, however, cannot be made. From Figures 6 to 11, it may be noted that the strain required to develop this angle of internal friction for mixtures 2 to 6 inclusive, in a wet condition was about 2.5 times that required to develop the angle of internal friction for mixture 1 at optimum moisture content. Thus if failure

were taken to mean an excessive deformation of a pavement at a given load, or repetition of loads, then it is possible that "failure" may have in fact taken place with mixtures 2 to 6 inclusive, in a wet condition, before the maximum load had been applied.

Table VII shows the deviator stress required to produce the same strain for mixtures 1 to 6 in a wet condition, as was required at failure for mixture number 1 at optimum moisture content. It may be seen that the deviator stress was, in all cases, much lower for the wet material than it was for the original material at optimum moisture content, and was in many cases lower for mixtures 2 to 6 in a wet state than it was for the original material in a wet state.

Whether or not these large strains would be required to develop the potential angle of internal friction within the crushed or washed aggregate, in a wet condition, under field conditions is a moot question. The main factor which might influence this is that in the field there would be much less lateral restraint during compaction and therefore it is possible that a better particle arrangement might be effected.

TABLE VII

DEVIATOR STRESS REQUIRED TO PRODUCE THE FAILURE STRAIN OF MIXTURE NO. 1 COMPACTED AT OPTIMUM MOISTURE CONTENT

Mixture Number	Lateral Pressure Kgm/sq. cm.	Strain %	Deviator Stress at Given Strain Kgm/sq. cm.
1 (opt.)	0.30	2.14	1.96
1 (wet)	"	"	1.41
2 (wet)	"	"	1.68
3 (wet)	"	"	1.30
4 (wet)	"	"	1.66
5 (wet)	"	"	1.32
6 (wet)	"	"	1.30

TABLE VII (Continued)

Mixture number	Lateral Pressure Kgm/sq.cm.	Strain %	Deviator Stress at Given Strain Kgm/sq.cm.
1 (opt.)	0.60	3.30	2.94
1 (wet)	"	"	2.16
2 (wet)	"	"	2.55
3 (wet)	"	"	1.96
4 (wet)	"	"	2.48
5 (wet)	"	"	2.20
6 (wet)	"	"	2.02
1 (Opt.)	0.90	3.47	3.73
1 (wet)	"	"	2.23
2 (wet)	"	"	3.10
3 (wet)	"	"	2.05
4 (wet)	"	"	3.19
5 (wet)	"	"	2.60
6 (wet)	"	"	1.35

It might also be argued that as mixtures 2 and 3 contained less minus #200 sieve material than the original mixture, the migration of capillary moisture in these mixtures would be less than for the original material. This should mean that there would less moisture in the granular base to cause failure. It is felt, however, that there was not a sufficient reduction in the minus #200 sieve material of mixtures 2 and 3 to materially reduce the migration of capillary moisture within such mixtures when used as base courses. This was evidenced by the fact that the permeability of mixture 3 was found to be very low.

As the loss of stability is due mainly to a reduction in intergranular stresses, brought about by an increase in pore water pressure under a load, only those base course materials which are extremely permeable show no loss in stability with an increase in moisture content (12). On the other hand, nearly saturated base course materials which contain an excess of plastic fines are so slow draining that there is insufficient

time for the dissipation of the excess pore water pressure during the loading time, which, in the case of highways, may be considered to be instantaneous. As, in this investigation, an excess of fines existed in all samples, there was a marked reduction in stability with an increase in moisture content noted in all cases.

Where the material was compacted and tested at optimum moisture content, there were sufficient air voids present in the specimen to provide a compressible medium which permitted the rapid dissipation of excess pore water pressure under the loads applied. The intergranular stresses were therefore not greatly reduced and higher angles of internal friction were noted for crushed and cleaned material. Where the material was compacted closer to a saturated condition, sufficient compressible air voids were not available to adequately dissipate the excess pore water pressure and, it is thought, the higher stresses were not achieved at high strains because of the high strains, but simply because there was a longer time available for dissipation of the excess pore water pressure. Thus the intergranular stresses were not as fully developed as was the case for the same materials at optimum moisture content. The developed intergranular stresses at failure, however, were greater for the crushed and washed aggregate in a wet condition than for the original aggregate in a similar condition and thus it might be assumed that crushing and washing are beneficial.

Several factors were noted which tend to substantiate the above conclusions. The permeability of mixture No. 3, which had the lowest percentage of minus #200 material, was so low that in trying to saturate the specimen by allowing the bottom of the specimen access to

deaired distilled water while applying a vacumm of 0.90 kgm/ sq. cm. to the top of the sample, the water had advanced only 4 inches up the specimen in 72 hours. At the same time the vacuum had dried the top 4 inches of the specimen to such an extent that it appeared, to all intents and purposes, as an air dry sample.

Before it was decided to line the rubber membrane with felt, and thus provide a drainage path for the excess pore water pressure within the specimens, the specimens would slump under little more than their own weight. Under field conditions this drainage path would normally not be available and thus little benefit would be derived from crushing, and benefit from washing would become apparent only when washing of the aggregate was sufficient to increase the permeability of the aggregate to such a point where it would be essentially free draining.

It may be concluded, therefore, that crushing or washing an aggregate containing an excess of low plastic fines may indicate an improvement in the stability of the aggregate, as determined by an increase in the angle of internal friction at failure when the aggregate is tested by vacuum triaxial test methods. This improvement is effective only when the rate of loading is sufficiently slow that the excess pore water pressure is dissipated as loading proceeds. As highway loads are repetitive and virtually instantaneous, the excess pore water pressure cannot be dissipated due to the low permeability of such an aggregate. The potential increase in angle of internal friction, therefore, cannot be fully utilized and thus aggregates containing an excess of low plastic fines remain very susceptible to loss of stability at high moisture contents.

As triaxial test moisture contents of the Winger gravel did not approach those at which failure occurred in the field, see Figure A, it is assumed that failure occurred at higher degrees of saturation than those obtained in the laboratory. No record of field density tests exists, and thus this assumption cannot be substantiated. However, if a field density of 132 lbs./ cu.ft. had been obtained, 100 per cent saturation occurred at a moisture content of 10 per cent.

PART B

AN INVESTIGATION INTO THE EFFECT OF PORTLAND CEMENT AND LIME FLY-ASH ADMIXTURES UPON THE PLASTICITY CHARACTERISTICS OF FINES FROM CRAWFORD PIT GRAVEL WHICH HAD AN EXCESS OF MEDIUM PLASTIC FINES

CHAPTER VII

CLASSIFICATION AND ANALYSIS OF MATERIALS INVESTIGATED

The source of the gravel used in this part of the investigation was the Crawford Pit (SW 33-36-20-4) near Stettler, Alberta. A visual examination of the native gravel, as well as grading and Atterberg Limit tests, showed that the material corresponded to the GF soil group of the Casagrande Airfield Classification system (1), and to an A-2-6 soil with a Group Index value of 0 as determined by the AASHO Classification system (2).

Table VIII shows the average results of twelve sieve analysis and Atterberg Limit tests carried out by the Testing Laboratory of the Alberta Department of Highways and reported by Clark (3).

TABLE VIII

MECHANICAL ANALYSIS AND PLASTICITY TESTS - CRAWFORD PIT

Oversize (+ 3") 6%

Sieve	% Passing	Atterberg Limits on - #40 Portion
3"	100	
1½"	90	Liquid Limit 35.8
3/4"	73	
#4	40	Plastic Limit 19.5
#10	25	
#40	14	Plasticity Index 16.3
#200	8.9	

The analyses of the quick lime and fly-ash used in this investigation were reported by Clark (3). The cement used was normal portland, type I.

The actual sieve analysis and Atterberg Limits of the Crawford

Aggregate used in this part of the investigation were as follows:

Sieve	% Passing
3"	100
1½"	93
3/4"	75
#4	43
#10	29
#40	17
#200	11.2

Atterberg Limits on minus #40 Portion	
Liquid Limit	38.5
Plastic Limit	20.3
Plasticity Index	18.2

CHAPTER VIII

APPARATUS AND PROCEDURES USED

The Atterberg Limit Tests performed on the minus #40 sieve portion of the Crawford gravel, and mixtures of the Crawford fines and additives, were carried out as recommended by Lambe (16) for determining the Liquid and Plastic Limits.

The Liquid and Plastic limits determined were as follows:

a) On original Crawford pit fines (minus #40 sieve portion) 5 hours after mixing with water.

b) On original Crawford pit fines with 2% normal portland cement additive, 1 hour, 6 hours, 26 hours, 7 days and 28 days after mixing with distilled water.

c) As for (b) with 5% normal portland cement additive.

d) As for (b) but with 8% normal portland cement additive.

e) As for (b) but with 1% quicklime and 2% fly-ash additive.

f) As for (b) but with 2% quicklime and 4% fly-ash additive.

g) As for (b) but with 3.5% quicklime and 7% fly-ash additive.

Where an addition of cement or lime fly-ash was made, these additives were mixed into the Crawford fines when both were air dry, before distilled water was added.

Sufficient material, approximately 1200 grams, was mixed with water to carry out each of the limit tests at all curing times required. This was done in order that there would be no variation in material from one curing period to another. In all cases, the curing was accomplished in a closed container and at a moisture content between the plastic and liquid limits. When a test was to be performed, approximately 200 grams

was removed from the container, mixed with water to a smooth paste and the limits were then carried out.

It was noted that the major reduction in the plasticity index of the fines was due to an immediate increase in the plastic limit upon the addition of portland cement. Further plastic limit tests were therefore carried out one hour after mixing to determine the effect upon the plastic limit produced by various percentages of portland cement additive. These plastic limit tests were carried out on the following mixtures:

a) Crawford fines with 0.5% normal portland cement added.

b) As for (a) but with 1.0% cement added.

c) As for (a) but with 1.5% cement added.

d) As for (a) but with 2.5% cement added.

e) As for (a) but with 6.5% cement added.

f) As for (a) but with 9.0% cement added.

From Figure 15 it may be seen that there was no immediate increase in plastic limit larger than that produced by the addition of 3 per cent cement. In order to estimate the amount of cement to be used in forming the triaxial specimens, it was assumed that the quantity of cement required by the minus #40 sieve portion of the gravel was 3 per cent as determined above. The quantity of cement required by the plus #40 sieve portion was determined by assuming that the ratio of weight of cement to surface area of aggregate was the same for the plus #40 sieve portion as for the minus #40 sieve portion. Surface areas were determined using the sieve analysis of the aggregate and surface area factors as given by the California Department of Highways.

(See Figure No. 18, Appendix A). Details of the calculations are shown in Appendix A. In this instance, the cement required by weight of dry minus 3 inch aggregate, which was to be used in forming triaxial specimens, was found to be 0.45%, which was rounded off to 0.5%.

The molding water content to be used in forming the triaxial specimens was determined by carrying out a compaction test on the minus #4 sieve portion of the gravel with the cement added. The compactive effort was half of standard proctor compaction. The percentage of cement used for the compaction test was determined using the surface area as above. The plus #4 sieve gravel was assumed to have an absorption of 1 per cent.

The weights of each of the 9 aggregate sizes required to form a 240 lb. batch for forming the specimen were determined in the same fashion as those for the Winger Pit. An attempt was made to reproduce the actual pit gradation. The batches for the compaction test were computed in a similar fashion using only minus #4 sieve material.

The apparatus and procedures used to carry out the triaxial tests on Crawford pit material were as discussed in part A of this investigation with the following exceptions:

a) Lateral pressure of 0.30 kgm/ sq. cm. only was used.

b) The triaxial specimen containing 0.5 per cent normal portland cement, which was to be tested at a moisture content above optimum, was saturated in 12 hours by allowing the bottom of the specimen access to de-aired distilled water while a vacuum of 0.90 kgm/sq. cm. was applied to the top of the specimen. This was the only specimen of the entire investigation where this procedure

was successful.

c) The cement was added to the dry fines and mixed thoroughly before the entire mixture was mixed, water added,and then remixed. This was to insure that the cement was well distributed throughout the entire specimen.

CHAPTER IX

TESTING PROGRAMME RESULTS:

The results of testing programme on the plasticity of the minus #40 sieve portion of the Crawford gravel with various additives are as shown in Table IX and Figures 13, 14 and 15.

TABLE IX

PLASTICITY CHARACTERISTICS OF MINUS #40 SIEVE CRAWFORD GRAVEL WITH VARIOUS ADDITIVES

MATERIAL TESTED	CURING TIME	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
Crawford fines (no additives)	5 hrs.	38.5	20.3	18.2
Fines ≠ 0.5%Cement	1 hr.	-	21.9	-
Fines ≠ 1.0%Cement	1 hr.	-	24.7	-
Fines ≠ 1.5%Cement	1 hr.	-	26.4	-
Fines ≠ 2.0%Cement	1 hr.	42.0	28.5	14.5
	6 hrs.	38.7	28.5	10.2
	26 hrs.	38.8	29.3	9.5
	168 hrs.	39.9	30.1	9.8
	680 hrs.	40.0	29.4	10.6
Fines ≠ 2.5%Cement	1 hr.	-	27.6	-
Fines ≠ 5% Cement	1 hr.	35.4	29.1	6.3
	6 hrs.	40.7	33.1	7.6
	36 hrs.	40.2	32.7	7.5
	196 hrs.	43.1	34.1	9.0
	678 hrs.	45.8	39.1	6.7
Fines ≠ 6.5%Cement	1 hr.	-	29.1	-

MATERIAL TESTED	CURING TIME	LIQUID TIME	PLASTIC LIMIT	PLASTICITY INDEX
Fines + 8.0% Cement	1 hr.	35.6	29.0	6.6
	6 hrs.	37.9	30.0	7.9
	32½ hrs.	39.8	32.8	7.0
	199 hrs.	43.7	37.4	6.3
	690 hrs.	45.6	39.8	5.8
Fines + 9.0% Cement	1 hr.	-	28.1	-
Fines + 1% Lime	1 hr.	36.5	30.7	5.8
+ 2% Fly-ash	6 hrs.	34.6	26.8	7.8
	24 hrs.	36.4	29.6	6.8
	193 hrs.	36.8	26.5	10.3
	866 hrs.	40.0	28.4	11.6
Fines + 2% Lime	1 hr.	30.9	24.3	6.6
+ 4% Fly-ash	6 hrs.	30.8	24.0	6.8
	24 hrs.	33.0	25.7	7.3
	193 hrs.	36.2	26.8	9.4
	866 hrs.	39.6	33.9	5.7
Fines + 3.5% Lime	1 hr.	32.7	27.7	5.0
+ 7% Fly-ash	6 hrs.	34.8	26.8	8.0
	24 hrs.	31.1	24.5	6.6
	196½ hrs.	35.0	27.4	7.6
	866 hrs.	39.1	30.3	8.8

It was noted that when cement was used as an additive, there was an immediate reduction in plasticity index, due in the most part, to an increase in plastic limit. A plot of plastic limit versus percent of cement added is shown in Figure 15.

All data sheets for this part of the investigation are contained in Appendix C.

Triaxial compression test results for the Crawford gravel are shown in Table X and Figure 16.

TABLE X

TRIAXIAL COMPRESSION TEST RESULTS OF CRAWFORD GRAVEL (-3")

ADDITIVE	CURING TIME	MOIST UNIT WEIGHT	DRY UNIT WEIGHT	MOISTURE CONTENT	LATERAL PRESSURE	DEVIATOR STRESS AT FAILURE	STRAIN AT FAILURE
		lbs./cu.ft.	lbs./cu.ft.	%	Kgm./sq.cm.	Kgm./sq.cm.	%
* None	None	123.3	118.1	4.45	0.305	1.86	1.66
None	None	140.2	130.6	7.4	0.30	1.75	5.95
0.5% N.P. Cement	None	130.0	122.0	6.6	0.30	2.23	1.64
0.5% N.P. Cement	12 Hrs.	132.1	124.7	10.8	0.30	1.21	2.45
** 2% H.E. Cement	24 Hrs.	128.8	122.3	5.4	0.31	4.31	1.12
*** 5% H.E. Cement	24 Hrs.	130.1	123.7	5.2	0.31	6.38	0.78
** 2% Lime and 4% Fly-ash	None	126.8	120.2	5.5	0.31	3.02	1.26
** 3.5% Lime and 7% Fly-ash	None	127.0	119.8	6.0	0.31	2.94	1.48
** 3.5% Lime and 7% Fly-ash	1 week	125.2	119.3	5.0	0.31	3.55	1.34

* Average of 6 tests reported by Clark (3)
** One test reported by Clark
*** Average of 2 tests reported by Clark

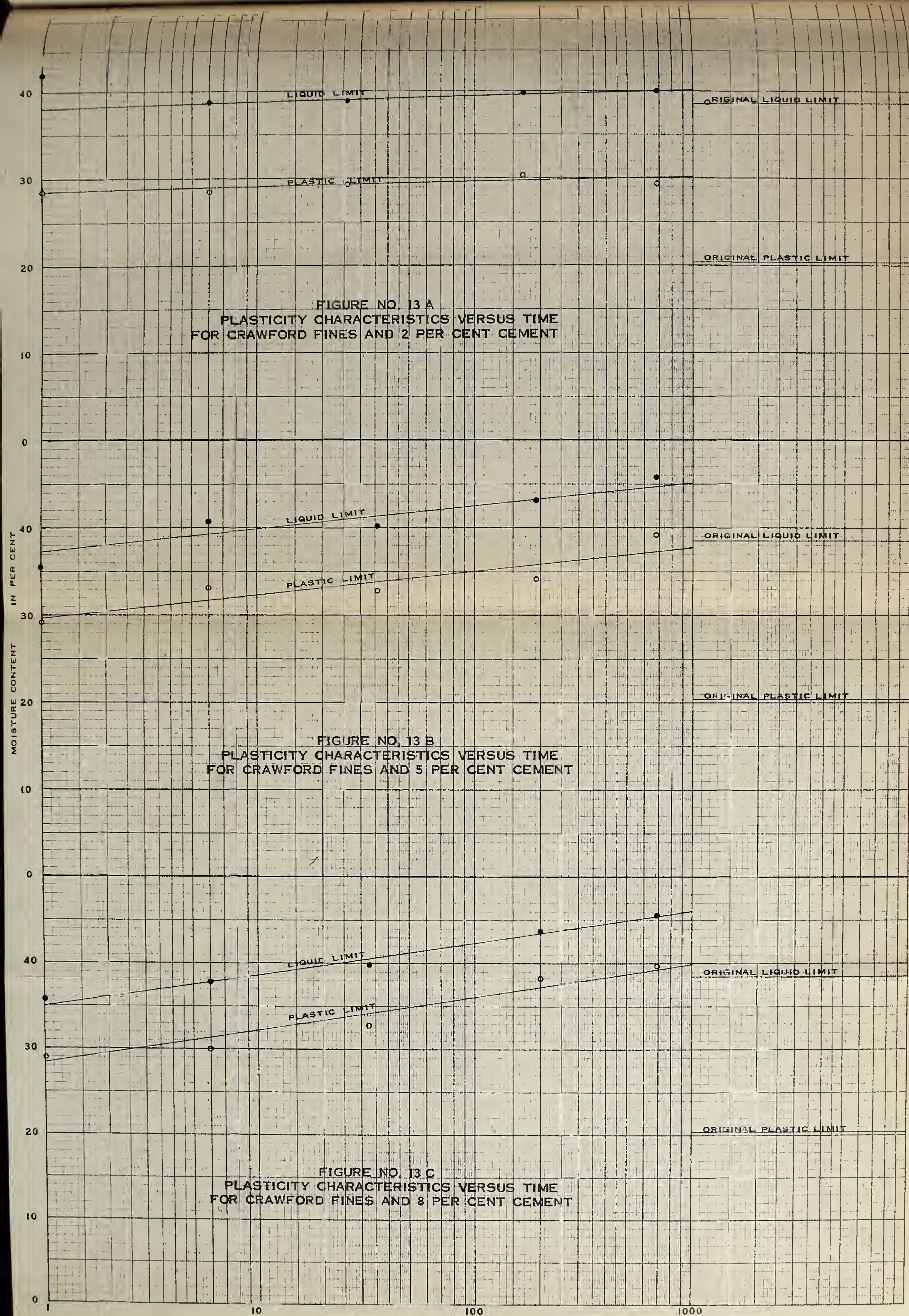


FIGURE NO. 13 A
PLASTICITY CHARACTERISTICS VERSUS TIME
FOR CRAWFORD FINES AND 2 PER CENT CEMENT

FIGURE NO. 13 B
PLASTICITY CHARACTERISTICS VERSUS TIME
FOR CRAWFORD FINES AND 5 PER CENT CEMENT

FIGURE NO. 13 C
PLASTICITY CHARACTERISTICS VERSUS TIME
FOR CRAWFORD FINES AND 8 PER CENT CEMENT

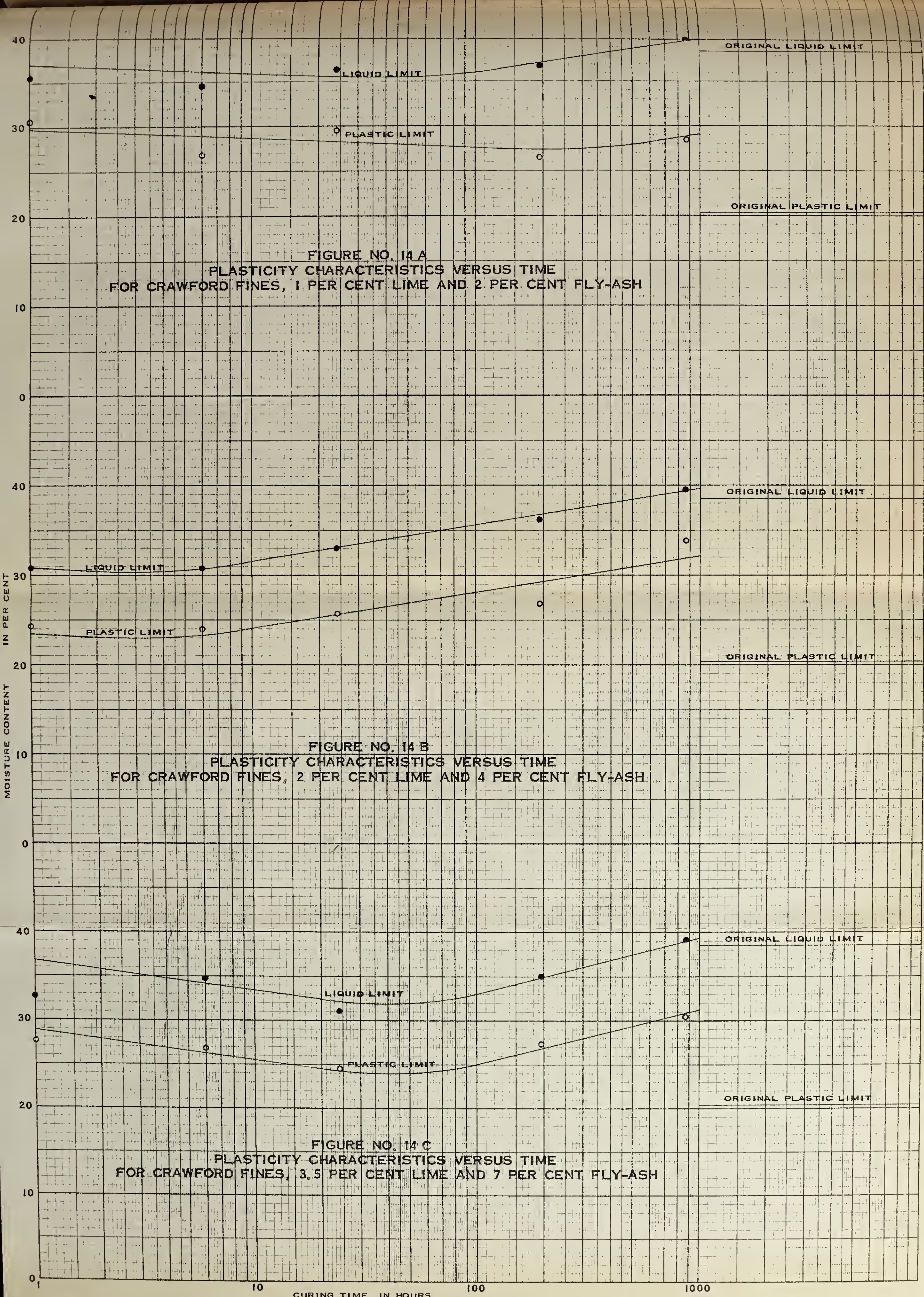


FIGURE NO. 14 A
PLASTICITY CHARACTERISTICS VERSUS TIME
FOR CRAWFORD FINES, 1 PER CENT LIME AND 2 PER CENT FLY-ASH

FIGURE NO. 14 B
PLASTICITY CHARACTERISTICS VERSUS TIME
FOR CRAWFORD FINES, 2 PER CENT LIME AND 4 PER CENT FLY-ASH

FIGURE NO. 14 C
PLASTICITY CHARACTERISTICS VERSUS TIME
FOR CRAWFORD FINES, 3.5 PER CENT LIME AND 7 PER CENT FLY-ASH

PLASTIC LIMIT VERSUS PER CENT CEMENT FOR CRAWFORD FINES

CURING TIME 1 HOUR

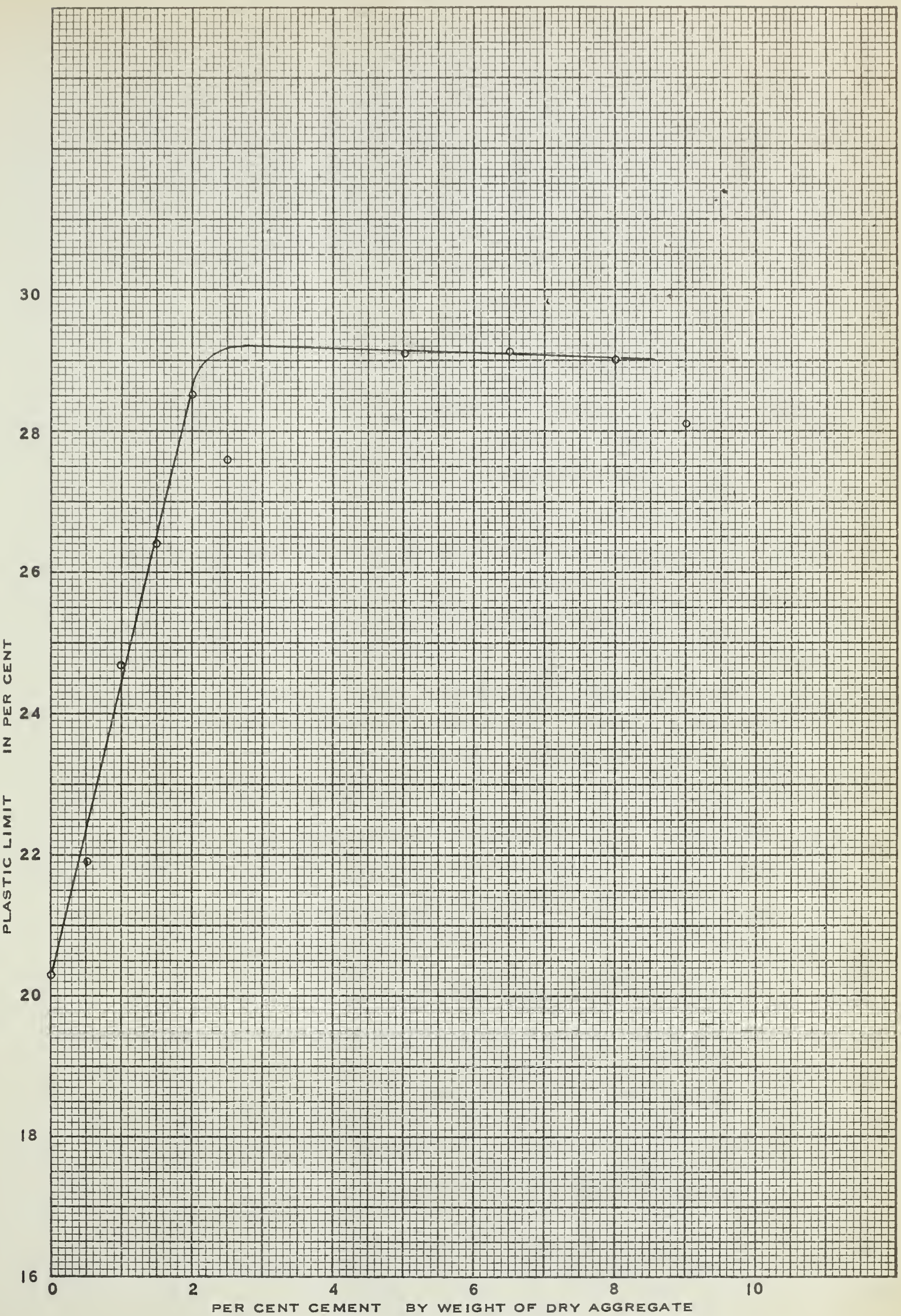
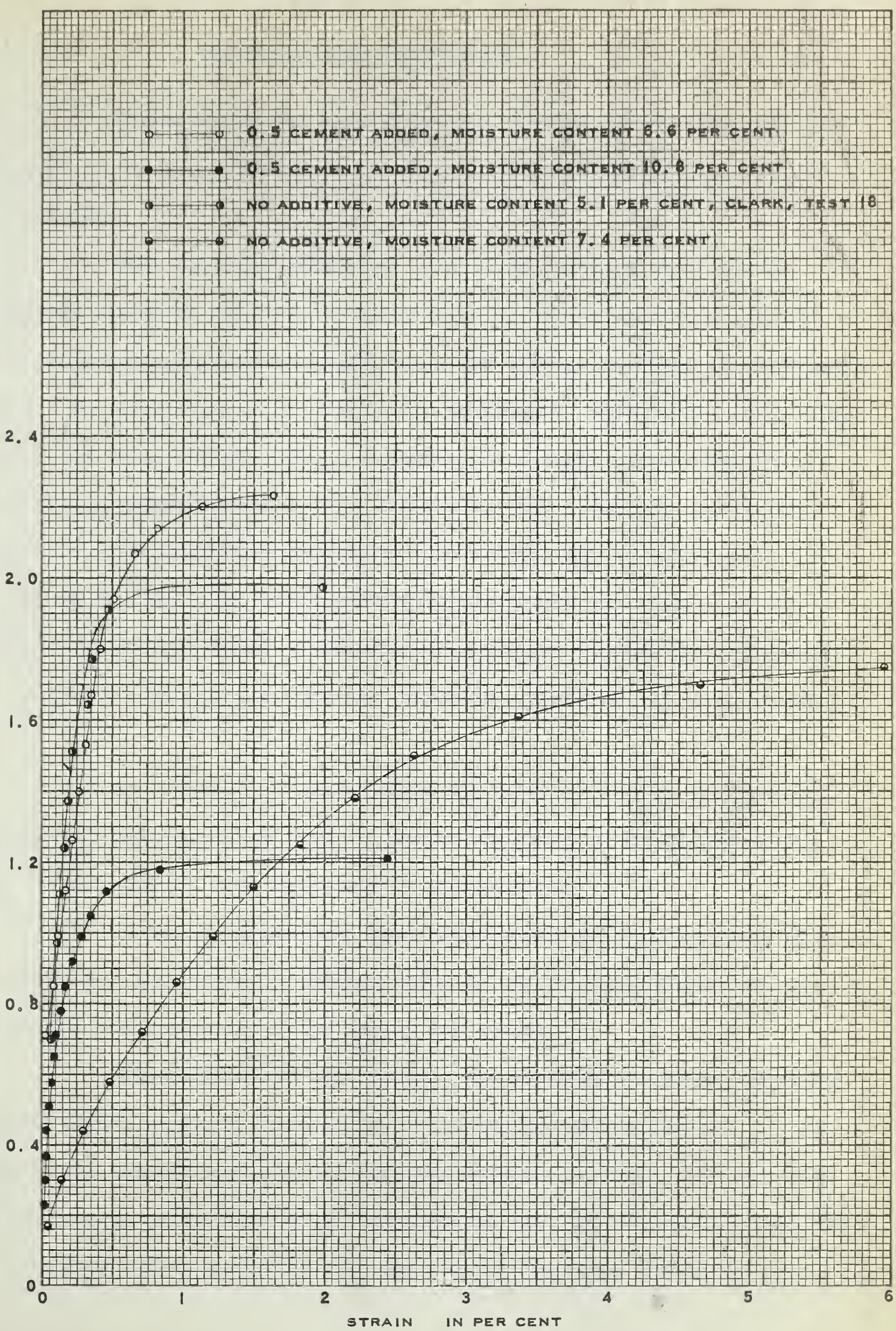


FIGURE NO. 15

FIGURE NO. 16

STRESS STRAIN CHARACTERISTICS FOR CRAWFORD PIT GRAVEL
AT A LATERAL PRESSURE OF 0.30 KGM./SQ. CM.



CHAPTER X

DISCUSSION AND CONCLUSIONS

A summary of the results of this portion of the investigation (Figures 13 to 16 and Tables IX and X) permit the following conclusions to be drawn:

When portland cement was used as an additive there was an immediate reduction in the plasticity index of the gravel fines made up of a slight decrease in the liquid limit and a large increase in the plastic limit. The plasticity index thereafter remained a constant as curing took place, the value of the constant depending to a small degree upon the quantity of cement used over 3%. Below a minimum amount of cement, in this case 3% as determined by plastic limit tests and as illustrated in Figure 15, the value of the plasticity index was dependent upon the quantity of cement added. A definite relationship between the percentage of cement and the plastic limit was noted for quantities of cement below 3%.

As curing took place, after the initial increase in plastic limit, both the liquid and plastic limits increased at a constant rate which was dependent upon the quantity of cement used.

It may be noted that after 1,000 hours the plastic limit of the fines was approximately the same value as the original liquid of the untreated fines, when 5% and 8% cement was added.

When 0.5% cement was added to the triaxial specimens, definite changes in the strength characteristics of the gravel were noted. In the case of the gravel compacted near optimum moisture content, the stability of the gravel, as measured by the deviator stress, was 20% greater than that of untreated native gravel at the same lateral pressure. This was true

even though the gravel with the cement contained almost 50% more water than that of the untreated gravel. The strains at failure were virtually identical in both cases.

The permeability of the gravel with 0.5% cement was increased to such an extent that of all the triaxial tests carried out, both for the Winger and Crawford gravels, this material was the only one which could be saturated by vacuum in 12 hours. This accounted for the high moisture content used for testing.

The addition of 0.5% of cement to the triaxial specimen, however, did not prevent a large loss of stability due to increased moisture content. At strains of less than 1% much higher stabilities were noted for the treated gravel at 10.8% moisture, than for the untreated gravel at 7.4% moisture. Thus for strains of less than 1%, higher stabilities were recorded for treated gravel, both near optimum moisture content and in a wet condition, than for untreated gravel in similar moisture conditions. (See Figure 16).

Where lime and fly-ash were used as additives, an immediate decrease in plasticity index of the fines was also observed (Figure 14). This was made up both by an increase in plastic limit and a decrease in liquid limit. The initial increase in the plastic limit of the fines plus the increase in plastic limit with time is likely the reason for the "drying" effect of the additive as noted by others (17). It would also explain the need for a higher optimum moisture content for compaction (21) (22) (3).

The time effect upon the plasticity characteristics produced by lime and fly-ash was an initial decrease in both the liquid and plastic limits from those obtained one hour after mixing. As curing started, however,

both the liquid and plastic limits increased in a similar fashion to that noted where portland cement was used as an additive. (See Figure 14).

CHAPTER XI

DISCUSSION OF TEST RESULTS

When a load is applied to a saturated soil, the total stress within the soil is made up of the neutral stress, or that portion of total stress carried by the pore water, and the effective stress, that portion of the total stress carried by the soil skeleton at the points of contact of the soil particles. When a granular, free draining soil is loaded, the excess pore water pressure is quickly dissipated by migration of the water from the pores, and the neutral stress within the specimen becomes zero. The total stress, total load divided by the area over which this load acts, then is equal to the resulting effective stress.

When a fine grained saturated soil is subjected to rapid loading, the neutral stress cannot be dissipated rapidly due to the low permeability of the soil. This results in the effective stress being lower than the total stress by the amount of the existing neutral stress. The shearing strength of a soil is the product of the effective stresses within the soil, and the coefficient of internal friction of the soil. Therefore the shearing resistance of a fine grained soil tested under slow test conditions in which the neutral stresses are dissipated by drainage after each increment of load, is higher than that of the same soil tested under quick test conditions. Under quick test conditions, the specimen is not permitted to drain during loading and thus there is no dissipation of the neutral stress.

In the case of partially saturated fine grained soils tested under quick test conditions, the neutral stress is partially dissipated by compression of the air voids with a resulting volume reduction in the specimen. The reduction of the neutral stress is inversely proportional

to the degree of saturation of the specimen. Thus the shearing strength of a partially saturated fine grained soil is inversely proportional to the moisture content of the soil at any given void ratio.

Both the Winger and Crawford gravels exhibited properties of a fine grained soil due to the excess of plastic fines contained in both gravels. The vacuum triaxial tests carried out permitted drainage, but the rate of testing was sufficiently rapid that drainage could not take place due to the low permeability of the gravels. Thus the main cause for decrease in stability of a gravel, with an excess of plastic fines, with an increase in moisture content, is due to the low permeability of the gravel.

Because the plastic fines adhere to the surface of sand and gravel particles, and because fine screens, which might be used to screen the clay and silt fraction from the gravel, are very expensive and fragile, screening the silt and clay from the sand and gravel to increase the permeability of the sand and gravel would be expensive and impractical.

Washing the sand and gravel to remove the clay and silt would be one method of increasing the permeability. This method has several drawbacks:

1) Due to the inefficiency of currently used washing plants, sand is washed out of the gravel with the silt and clay. If the silt and clay are to be removed, without removing the sand present, a costly flotation process may be necessary.
2) Extra cost is incurred in drying the washed aggregates.
3) A source of water for washing must be available. In many parts of the Prairie Provinces, an adequate supply of water may not be available at the site.

An increase in the permeability of the gravel may also be accomplished by the addition of trace quantities of portland cement to the gravel before placing and compacting. In the case of the Crawford gravel, the quantity of cement required was found to be 0.45 per cent by weight of dry gravel, as determined by plastic limit tests using varying amounts of cement additive, and from the grain size analysis. The cost of the cement would be approximately 21 cents per cubic yard of gravel treated, i.e. one-fifth of a bag per cubic yard of gravel. The extra handling, mixing and blending cost is estimated to amount to 14 cents per cubic yard of gravel treated. The cost figures used to compute the above are as follows:

a) Heavy farm tractor and pulvi-mixer, $5.00 per hour. This would mix 100 cubic yards per hour in two passes, and thus the cost of mixing would be 5 cents per cubic yard of gravel.

b) Blade grader for extra windrowing and blending required, $8.00 per hour. This would handle 400 cubic yards per hour and therefore the cost of extra blending would be 2 cents per cubic yard of gravel.

c) Cost of cement, $1.05 per sack

d) Handling required for the cement, 35 cents per sack. This would amount to 7 cents per cubic yard of gravel.

The total cost of adding 0.45 per cent cement to the original gravel would therefore amount to approximately 35 cents per cubic yard of gravel treated.

Unfortunately time did not permit an investigation of the effect of lime and fly-ash upon the permeability of the gravel. As the action of this additive is similar to that of the cement, however, it is thought that anincrease in permeability of the gravel would probably result from

the addition of a small amount of lime and fly-ash.

The cost of handling, mixing and blending the lime and fly-ash would be approximately the same as for cement, i.e. 14 cents per cubic yard of gravel treated. In order that the cost of lime and fly-ash be competitive with that of cement, the amount of lime and fly-ash is limited to a maximum of 0.2 per cent and 0.4 per cent respectively. This is based upon a compacted unit weight of gravel of 3500 lbs. per cubic yard, the cost of quicklime being $1.00 per 60 lb. sack and the cost of fly-ash being $16.00 per ton. It is not known whether or not these quantities would produce the desired results.

In addition to the increased shearing strength of the gravel at a high moisture content produced by an increase in permeability, the shearing strength could further be increased by an increase in the co-efficient of internal friction of the gravel. Triaxial test results, using the Winger Gravel, indicate a definite increase in the angle of internal friction of the gravel due to crushing. The angle of internal friction of the two-inch crushed gravel was higher than that of the original three-inch screened gravel, but less than that of the 1½-inch crushed gravel. Gravel crushed to one inch showed a small reduction in angle of internal friction from that obtained with the 1½ gravel.

It is suggested that future research attempt to correlate the permeability of compacted plastic fines, treated with cement and with lime and fly-ash, with the permeability of fines of a gravel known to be satisfactory for base course construction. It should be possible to determine a minimum permeability for base course gravel fines. This,

then, could be used as the basis for evaluating a source of base course gravel. Should the permeability of a proposed gravel source be below this minimum, the quantity of cement or of lime and fly-ash needed to increase the permeability could be determined from plastic limit tests and a grain size analysis of the gravel.

In addition, the weathering effects of cycles of freezing and thawing upon the plasticity characteristics of treated gravel fines should be investigated to determine the permanency of the plasticity changes after treating with cement and lime and fly-ash. This was not carried out in the current investigation.

CHAPTER XII

CONCLUSIONS

The conclusions arrived at in this investigation are as follows:

1) The loss of stability of a gravel, which contains an excess of plastic fines, due to an increase in moisture content results from the low permeability of the gravel.

2) The permeability of such a gravel may be increased by screening, washing, or by the addition of a small quantity of portland cement. It is assumed, also, that a similar increase in permeability would result from the addition of a small amount of lime and fly-ash.

3) Stability of a gravel, containing an excess of plastic fines, may be increased by crushing the gravel, thus increasing the coefficient of internal friction of the gravel. Crushing, however, does not effectively prevent a loss of stability due to an increase in moisture content for the reason given in (1) above. If the permeability of the gravel were to be increased, in addition to crushing, the potential increase in stability of the gravel due to crushing could be realized.

4) The effect of cement upon the plastic fines of a gravel is an immediate reduction in the plasticity index resulting from a large increase in the plastic limit and a small decrease in the liquid limit. Thereafter the plasticity index remains constant and the liquid and plastic limits

increased at a constant rate. Above a minimum amount of cement additive, there is no initial increase in the plastic limit with an increase in cement.

5) The effect of lime and fly-ash upon the plastic fines of a gravel is an immediate reduction in the plasticity index. This results from both an increase in the plastic limit and a decrease in the liquid limit. Both the liquid and plastic limits then show an initial reduction with time and then a constant increase as curing takes place.

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APPENDIX A

SAMPLE COMPUTATIONS.

ESTIMATING THE OPTIMUM MOLDING WATER CONTENTS FOR TRIAXIAL SPECIMENS

For this example, Mixture number 5 is used as it is typical of all cases.

From a compaction test on the minus #4 sieve portion of the gravel, it was found that the optimum moisture content was 11.5%. Mixture number 5 contained 35% minus #4 sieve before crushing, therefore for a total oven dry sample of 100 lbs., the water required for the original minus #4 portion was:

$$.35 \times 11.5 = 4.03 \text{ lbs.}$$

The quantity of minus #4 sieve produced by crushing was found from sieve analysis to be 9%. It was assumed that the optimum moisture content for this material was 5%. Thus the additional water required per 100 lbs. of total oven dry aggregate for the crusher fines was:

$$.09 \times 5 = .45 \text{ lbs.}$$

The absortion of the plus #4 sieve material was found from specific gravity tests to be 1.85%. Thus the water required for the remaining 56 lbs. of the 100 lb. sample was:

$$.56 \times 1.85 = 1.04 \text{ lbs.}$$

Thus the total water required at optimum moisture content was:

$$\frac{4.03 + .45 + 1.04}{100} = 5.5\%$$

PAVEMENT THICKNESS REQUIREMENTS USING THE KANSAS DESIGN METHODS.

1. Determining Saturation Coefficient **(n)**.

The 30 year average annual precipitation (1921-1950) for the Carstairs area was 17.5 inches and was obtained from the Edmonton Public Weather Office. From the table of saturation coefficients the value for n was found to be 0.6 (13) (14).

2. Determining the Traffic Co-efficient (m)

The maximum gross load in Alberta is 72,000 lbs. This would normally be distributed over a 5 axle tractor-trailer combination giving a maximum gross wheel load of 7200 lbs. if the weight were evenly distributed. For this analysis, however, a maximum wheel load of 9000 lbs. (4 axle tractor-trailer combination) was used. This load acts on dual wheels and is consistent with values obtained by the Alberta Highways Department. From the table of Traffic Coefficients, the value for m was found to be 1. (13) (14).

3. Choosing the Thickness Chart.

As a deflection factor, S = 0.1 inch, is common to all Kansas design charts, and as the saturation coefficient (n) was known to equal 0.6, design Fig. A-6 was chosen from reference (14). The design chart with m = 1 is illustrated in Figure 17.

4. Choosing the Thickness of Mat Required to cover the Base Course.

For this evaluation Mixture number 5 compacted over optimum moisture content will be used. As a lateral pressure of 20 p.s.i. is not possible with a vacuum triaxial test, the stress strain curve for a lateral pressure of 0.90 Kgm./sq.cm. is used, see Figure 10.

For the first trial, a deviator stress of 1.5 Kgm./sq.cm. was chosen. From Figure 10, the strain was found to be 1.15%.

Thus the stress difference (p.s.i.) was 21.4 p.s.i.

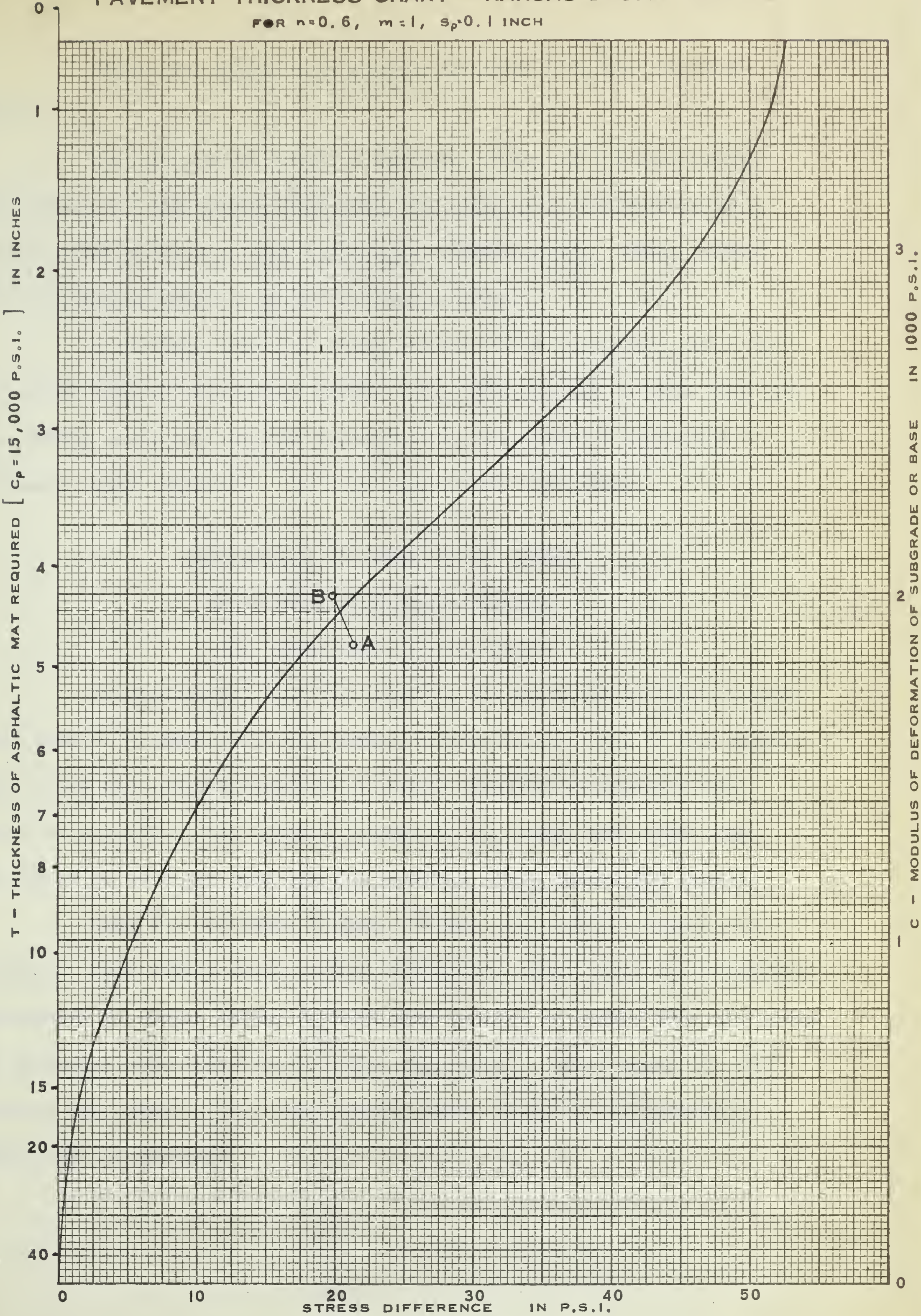
The modulus of Deformation was:

$$\frac{21.4}{.0115} = 1855 \text{ p.s.i.}$$

FIGURE NO. 17

PAVEMENT THICKNESS CHART - KANSAS DESIGN METHOD

FOR n=0.6, m=1, S_p=0.1 INCH



These two values were plotted as point A on the thickness chart.

For the second trial, a deviator stress of 1.4 Kgm./sq.cm. was chosen and the stress difference and modulus of deformation were found to be 19.9 p.s.i. and 1995 p.s.i. respectively. These values were plotted as point B on the thickness chart.

A straight line was drawn between these two points which fell on either side of the design curve. The intersection of this line and the design curve was used to determine the thickness of asphaltic pavement cover required. In this case it was 4.4 inches.

DETERMINING THE QUANTITY OF CEMENT TO BE USED IN FORMING TRIAXIAL AND COMPACTION TEST SPECIMENS

It was assumed that the quantity of cement to be used in each case should be proportioned according to the surface area of the aggregate using the optimum quantity of cement required by plastic limit tests as a basis. The optimum percentage of cement was found from Figure 15 to be 3 per cent for the Crawford fines (minus #40 sieve).

From the Materials Manual, Testing and Control Procedures, Volume 1, Test Method Calif. 303-B, January 3, 1956, State of California, Department of Public Works, surface area factors in square feet per pound of aggregate were found and plotted, Figure 18. From Figure 18, the surface area factors to be applied here were found by extrapolation. These were as follows:

PASSING SIEVE NUMBER	SURFACE AREA in sq. ft./lb.
3"	0.135
1½"	0.26
3/4"	1.0
#4	2.0
#10	4.6
#40	21
#100	58
#200	160

Taking a 100 lb. sample for use in forming the triaxial specimen

PASSING SIEVE	RETAINED ON SIEVE	WEIGHT OF AGG. (lbs.)	SURFACE AREA FACTOR (sq.ft./lb.)	SURFACE AREA (sq.ft.)
3"	1½"	10.0	.135	1
1½"	3/4"	17.0	.26	9
3/4"	#4	33.0	1.0	33
#4	#10	15.0	2.0	30
#10	#40	11.0	4.6	51
Subtotal		86.0		124
#40	#100	1.75	21	37
#100	#200	3.30	58	192
#200		8.95	160	1430
Subtotal		14.00		1659
Total		100.0		1783

The quantity of cement required for the minus #40 sieve portion was

$$\frac{3}{100} \times 14 = 0.42 \text{ lbs.}$$

Thus the quantity of cement, based on surface are, required for the plus #40 sieve portion was

$$\frac{124}{1659} \times 0.42 = 0.03 \text{ lbs.}$$

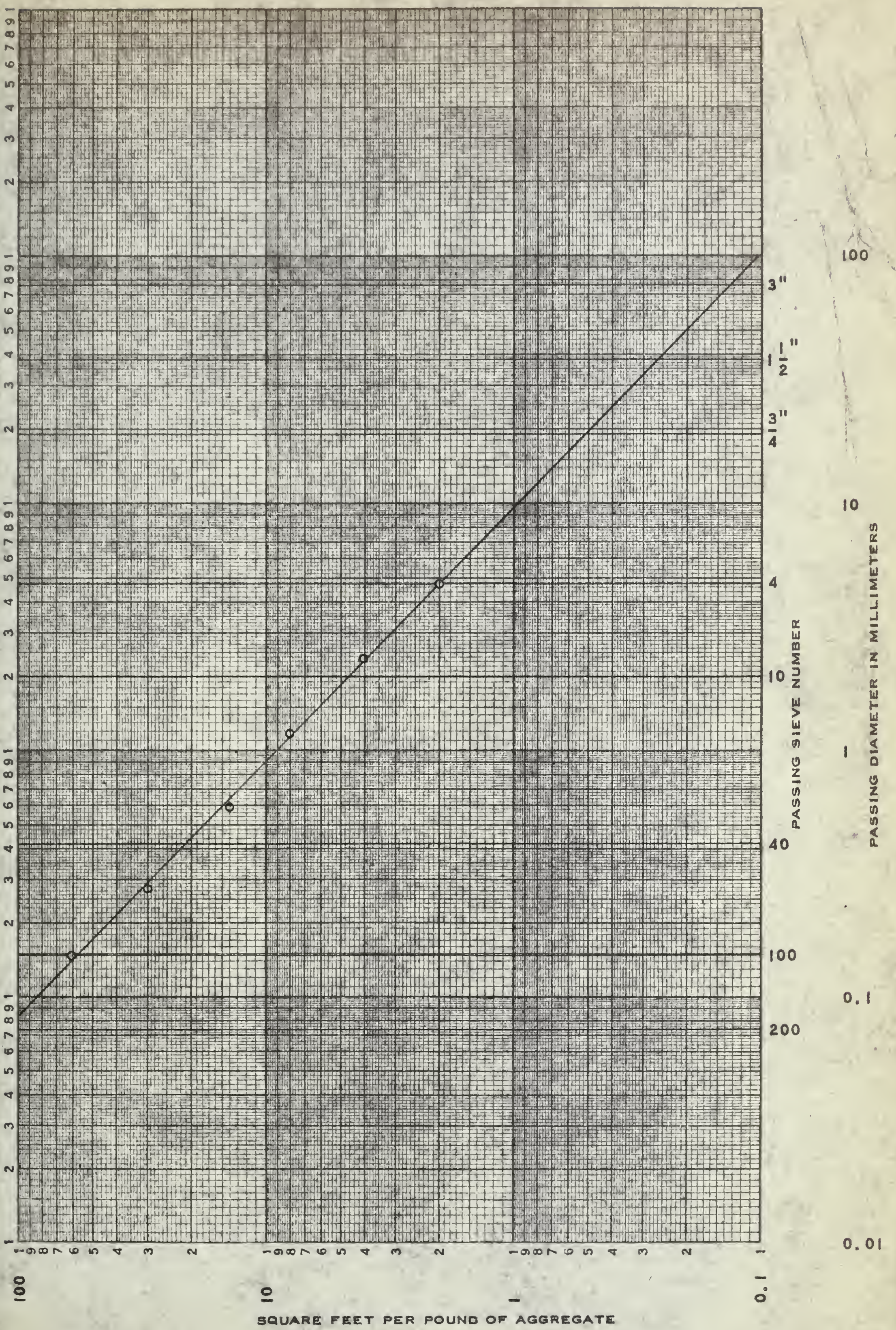
Therefore the quantity of cement required for the triaxial specimen was

$$\frac{0.42 + 0.03}{100} = 0.45 \text{ per cent by}$$

weight of dry aggregate.

The quantity of cement required for the compaction specimens was found in a similar manner, using #4 sieve material as the top size rather than 3" inch material. In this case it was computed to be 1.1 per cent cement.

FIGURE NO. 18
SURFACE AREA FACTORS
CALIFORNIA HIGHWAYS DEPARTMENT



APPENDIX B

DETAILED TEST DATA FOR PART A

UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
SPECIFIC GRAVITY

PROJECT			
SITE			
SAMPLE	WINGER – #4 FROM MIXTURE #1		
LOCATION	AND WINGER + #4 " "		
HOLE		DEPTH	
TECHNICIAN	K.A.H.	DATE	9/1/59

Sample No.	1	
Flask No.	15	
Method of Air Removal	VACUUM.	
W_{b+w+s}	919.60	
Temperature T	20.05 °C	
W_{b+w}	640.07	
Evaporating Dish No.	-	
Wt. Sample Dry + Dish	1378.25	
Tare Dish	932.60	
W_s	445.65	
G_s	2.68	

W_{b+w+s} = Weight of flask + water + sample at T°.
W_{b+w} = Weight of flask + water at T° (flask calibration curve).
W_s = Weight of dry soil
G_s = Specific gravity of soil particles = $\frac{W_s}{W_s + W_{b+w} - W_{b+w+s}}$

Determination of W_s from wet soil sample:

Sample No.			Sample No.		
Container No.			Container No.		
Wt. Sample Wet + Tare			Wt. Test Sample Wet + Tare		
Wt. Sample Dry + Tare			Tare Container		
Wt. Water			Wt. Test Sample Wet		
Tare Container			W_s		
Wt. of Dry Soil					
Moisture Content w %					

Description of Sample: WINGER + #4.

WEIGHT SAMPLE (S.S.D) + TARE 5328.00 — G_s BULK = $\frac{A}{B-C}$ = 2.58

WEIGHT TARE 1225.95 — G_s BULK (S.S.D) = $\frac{B}{B-C}$ = 2.63

(B) WEIGHT SAMPLE (S.S.D) 4102.05 — G_s APPARENT = $\frac{A}{A-C}$ = 2.71 *

~~Remarks~~: WT. SAMPLE (S.S.D) + BASKET IN WATER 3244.0 — ABSORPTION % = $\frac{B-A}{A} \times 100$ = 1.79

WT. BASKET IN WATER 702.2

(C) WT. SAMPLE (S.S.D) IN WATER 2541.8

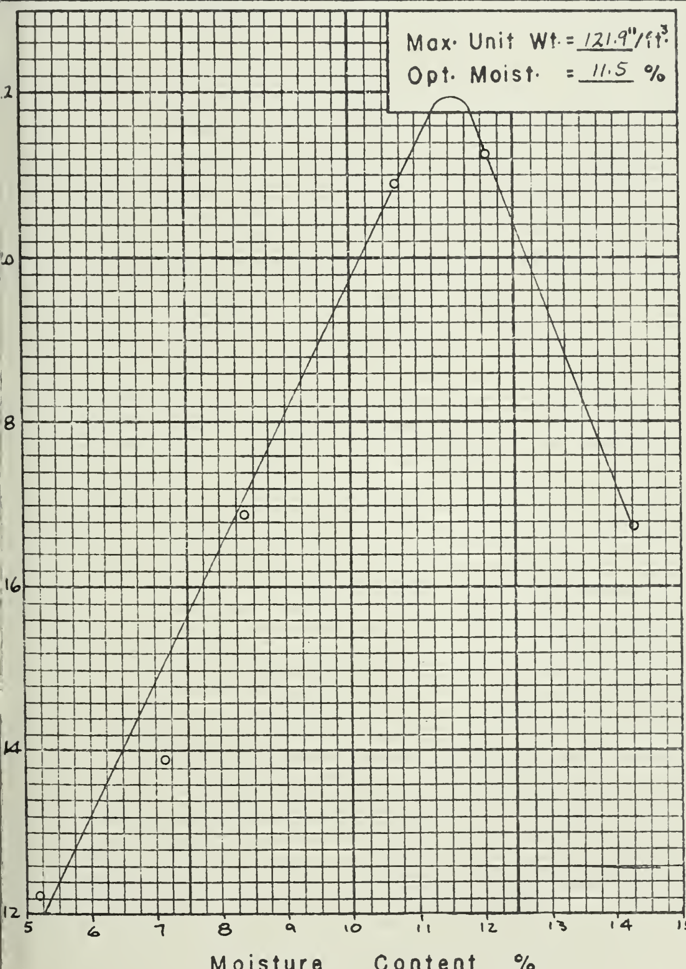
NOTE AVERAGE G_s FOR COMBINED COARSE & FINE AGGREGATES = 2.70

(A) WT. SAMPLE (OVEN DRY) 4029.9

UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
COMPACTION TEST

PROJECT
SITE
SAMPLE Winger — #4 from Mixture #1
LOCATION (also used for Mixtures 4, 5, 6)
HOLE DEPTH
TECHNICIAN K.A.H. DATE 29/12/58

Trial Number	1	2	3	4	5	6	
Mold No.	1	1	1	1	1	1	
Wt. Sample Wet + Mold	3521.1	3580.6	3649.8	3758.6	3789.4	3752.2	
Wt. Mold	1742.8	1742.8	1742.8	1742.8	1742.8	1742.8	
Wt. Sample Wet	1778.3	1837.8	1907.0	2015.8	2046.6	2009.4	
Volume Mold	1/30.12	1/30.12	1/30.12	1/30.12	1/30.12	1/30.12	
Wet Unit Weight lb./ft³	118.08	122.04	126.63	133.86	135.90	133.43	
Dry Unit Weight lb./ft³	112.23	113.90	116.89	120.92	121.26	116.77	
Container No.	V6	V67	V25	V64	V61	V41	
Wt. Sample Wet + Tare	144.12	147.99	156.00	146.75	162.82	185.07	
Wt. Sample Dry + Tare	140.83	142.71	150.53	139.00	153.54	171.00	
Wt. Water	3.29	5.28	5.47	7.75	9.28	14.07	
Tare Container	77.74	68.90	84.86	66.77	76.66	72.41	
Wt. Dry Soil	63.09	73.81	65.67	72.23	76.88	98.59	
Moisture Content	5.21	7.15	8.33	10.70	12.07	14.27	



Method of Compaction
Std. Proctor Mold & Tamper
1/2 Std. Proctor Energy
Diam. Mold ≏ 4.0"
Height Mold ≏ 4.6"
Volume Mold 1/30.12 cu. ft.
No. of Layers 3
Blows per Layer 13
Ht. of Free Fall 12"
Wt. of Tamper 5.5 #
Shape of Tamping Face O
Description of Sample

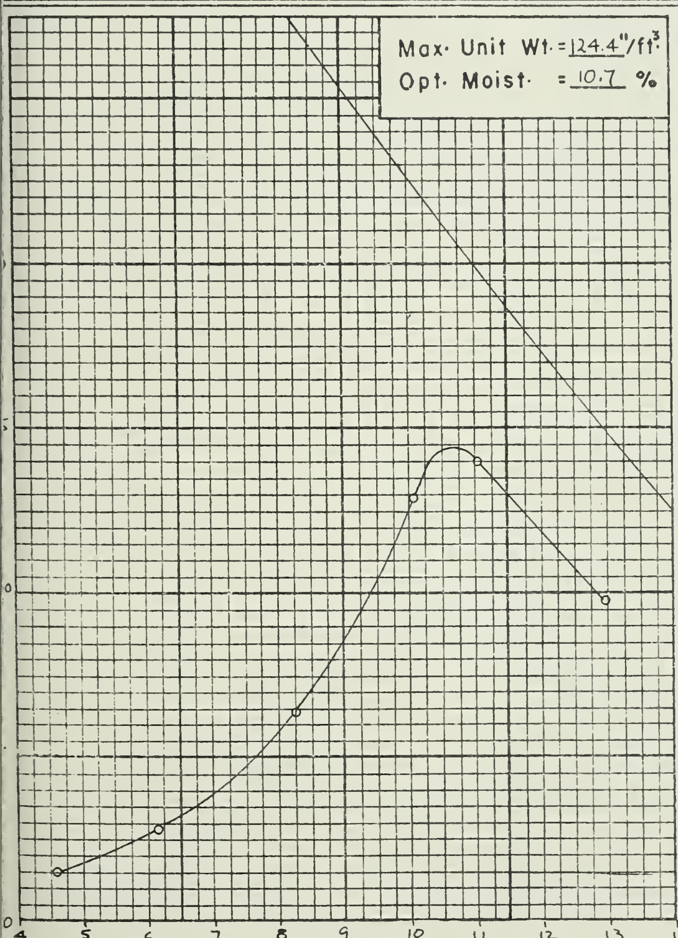
Remarks

UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

COMPACTION TEST

PROJECT
SITE
SAMPLE *Winger - #4 From Mixture #2*
LOCATION
HOLE DEPTH
TECHNICIAN *K. A. M.* DATE *29/12/58*

Number	1	2	3	4	5	6	
Mold No.	1	1	1	1	1	1	
Wt. Sample Wet + Mold	3499.1	3546.4	3640.9	3780.1	3816.0	3779.8	
Wt. Mold	1742.8	1742.8	1742.8	1742.8	1742.8	1742.8	
Wt. Sample Wet	1756.3	1803.6	1898.1	2037.3	2073.2	2037.0	
Volume Mold	1/30.12	1/30.12	1/30.12	1/30.12	1/30.12	1/30.12	
Wet Unit Weight lb./ft.^{3}	116.62	119.77	126.04	135.28	137.67	135.26	
Dry Unit Weight lb./ft.^{3}	111.46	112.79	116.43	122.88	123.99	119.74	
Container No.	V65	V63	V23	V62	V68	V24	
Wt. Sample Wet + Tare	115.71	136.09	129.44	119.05	166.92	166.78	
Wt. Sample Dry + Tare	113.59	132.11	124.86	114.10	158.99	156.58	
Wt. Water	2.12	3.98	4.58	4.95	7.93	10.20	
Tare Container	67.85	67.77	69.34	65.02	87.12	77.88	
Wt. Dry Soil	45.74	64.34	55.52	49.08	71.87	78.70	
Moisture Content	4.63	6.19	8.25	10.09	11.03	12.96	



Moisture Content %

Method of Compaction
Std. Proctor Mold & Tamper
1/2 Std. Proctor Energy

Diam. Mold ≏ 4.0"
Height Mold ≏ 4.6"
Volume Mold 1/30.12 cu. ft.
No. of Layers 3
Blows per Layer 13
Ht. of Free Fall 12"
Wt. of Tamper 5.5 lbs.
Shape of Tamping Face O
Description of Sample

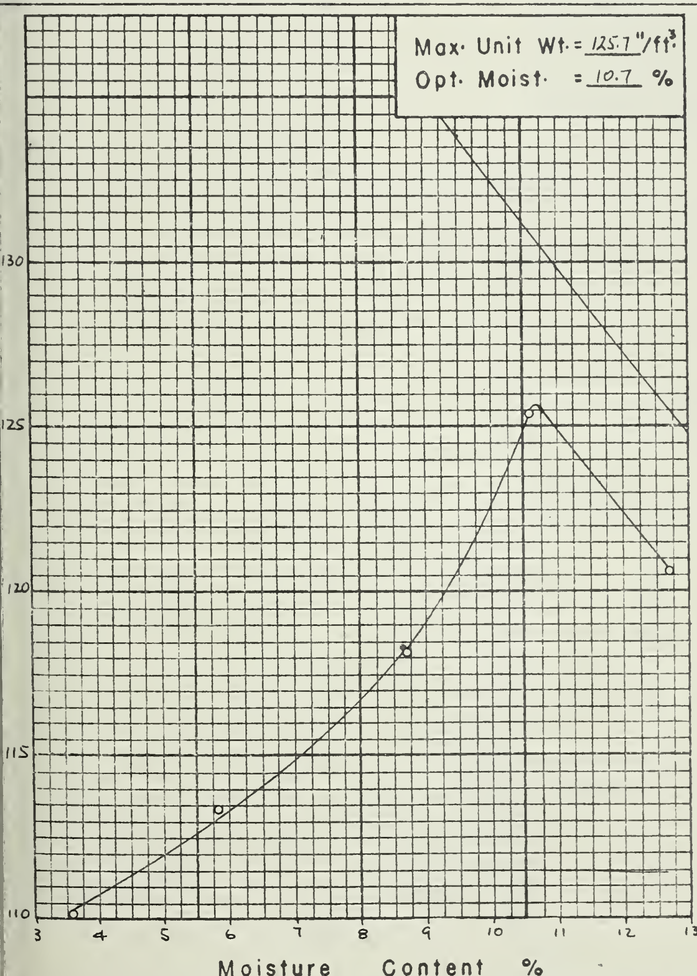
Remarks

UNIVERSITY of ALBERTA
DEP'T· of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

COMPACTION TEST

PROJECT
SITE
SAMPLE Winger - #4 From
LOCATION Mixture #3.
HOLE DEPTH
TECHNICIAN K.A.H. DATE 8/1/59

al Number	1	2	3	4	5	6	
Mold No·	1	1	1	1	1		
Wt· Sample Wet + Mold	3461.5	3549.9	3677.0	3831.7	3789.2		
Wt· Mold	1742.8	1742.8	1742.8	1742.8	1742.8		
Wt· Sample Wet	1718.7	1807.1	1934.2	2088.9	2046.4		
Volume Mold	1/30.12	1/30.12	1/30.12	1/30.12	1/30.12		
Wet Unit Weight lb·/ft³	114.13	120.00	128.44	138.71	135.89		
Dry Unit Weight lb·/ft³	110.16	113.42	118.16	125.42	120.58		
Container No·	V37	V71	A15	V46	V42		
Wt· Sample Wet + Tare	132.81	148.71	115.28	146.35	162.26		
Wt· Sample Dry + Tare	130.49	144.48	111.39	140.37	151.58		
Wt· Water	2.32	4.23	3.89	5.98	10.68		
Tare Container	66.62	72.04	66.64	83.69	67.38		
Wt· Dry Soil	63.87	72.44	44.75	56.68	84.20		
Moisture Content	3.6	5.8	8.7	10.6	12.7		



Method of Compaction
Std. Proctor Mold & Tamper
½ Std. Proctor Energy

Diam. Mold ≏ 4.0"
Height Mold ≏ 4.6"
Volume Mold 1/30.12 cu. ft.
No· of Layers 3
Blows per Layer 13
Ht· of Free Fall 12"
Wt· of Tamper 5.5 lbs.
Shape of Tamping Face O
Description of Sample

Remarks

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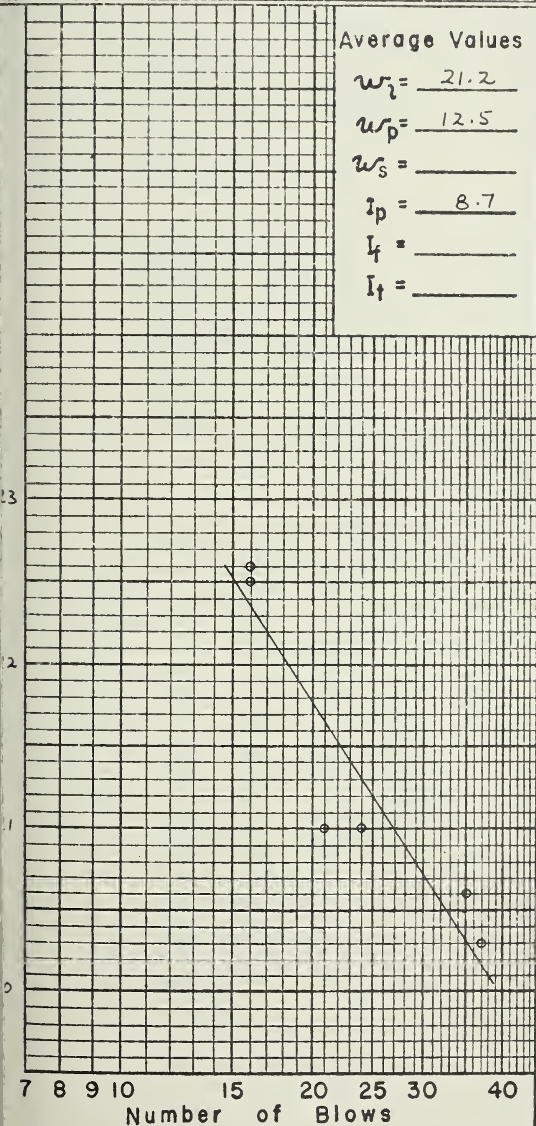
SOIL MECHANICS LABORATORY

ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	Winger minus #40
LOCATION	
HOLE	DEPTH
TECHNICIAN K.A.L.	DATE 17/12/58

Liquid Limit

al No.	1	2	3	4	5	6
. of Blows	21	23	16	16	35	37
ntainer No.	V23	V49	V46	V41	V74	V24
. Sample Wet + Tare	94.83	97.09	114.76	102.96	101.07	110.63
. Sample Dry + Tare	90.39	92.66	109.03	97.35	95.95	105.10
. Water	4.44	4.43	5.73	5.61	5.12	5.53
re Container	69.34	71.56	83.69	72.41	71.07	77.88
. of Dry Soil	21.05	21.10	25.34	24.94	24.88	27.22
isture Content w%	21.0	21.0	22.6	22.5	20.6	20.3



Average Values

w_l = 21.2

w_p = 12.5

w_s = ______

I_p = 8.7

I_f = ______

I_t = ______

Plastic Limit

Trial No.	1	2	3
Container No.	BY + BZ	AM + BJ	AV + AK
Wt. Sample Wet + Tare	62.9430	61.6262	65.0539
Wt. Sample Dry + Tare	61.9289	60.5377	63.8071
Wt. Water	1.0141	1.0885	1.2468
Tare Container	53.9418	51.8679	53.7869
Wt. of Dry Soil	7.9871	8.6698	10.0202
Moisture Content %	12.7	12.5	12.4

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V - V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V - V_o}{W_o} \times 100\right)$$

Description of Sample: ______

Remarks: ______

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SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE *Winger Pit - Mixture #1*
LOCATION
HOLE DEPTH
TECHNICIAN *K.U.M.* DATE *7/1/59*

Machine Data:–
Machine No. *T.O.*
Multiplication Factor —
Wt. Loading Block + Piston (gms.) *21 Kgm.*

Description of Sample:
Native gravel screened to 3" max.
Compacted at opt. moisture.

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure	(σ_{III}) *Kgm/sq.cm.*	0.30					
Length	inches	24 5/8					
Area	sq. cms.	730					
Volume	~~c.c.s.~~ *cu. ft.*	1.612					
Dry Unit Weight	lbs/cu.ft. γ_d	132.7					
Gs= ·Volume Soil Solids	γ_{wet}	139.6		*Wet soil*	*used*	*225*	*lbs.*
Wt. Tare + Soil + Water at start							
Wt. Tare + Soil + Water at end		5210					
Wt. Tare + Soil		4964					
Number and weight of Tare		214					
Wt. Soil		4750					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	246					
	Moisture content	5.18					
	Degree of saturation %	52					

Load on Pan	Dial Rdg	Strain	Area	$\sigma_I - \sigma_{III}$	Load on Pan σ_I	Dial Rdg.	Strain	Area	σ_I	Load on Pan	Dial Rdg.	Strain	Area	σ_I
m	ins.	%	cm²	Kgm/cm²	Kgm/cm²									
	0.926	–	730	.03	.33									
2	0.918	.03	730	.17	.47									
2	0.911	.06	730	.30	.60									
0	0.895	.13	731	.44	.74									
0	0.876	.20	731	.58	.88									
2	0.859	.27	732	.71	1.01									
0	0.843	.34	732	.85	1.15									
2	0.827	.40	733	.98	1.28									
0	0.809	.48	733	1.12	1.42									
0	0.792	.54	734	1.26	1.56									
0	0.772	.63	734	1.39	1.69									
0	0.745	.74	735	1.53	1.83									
20	0.717	.85	736	1.66	1.96									
0	0.672	1.03	737	1.79	2.09									
20	0.585	1.39	740	1.92	2.22									
20	0.400	2.14	746	1.96	2.26									

Failure by bulging.

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DEPT of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE *Winger Pit · Mixture #1*
LOCATION
HOLE DEPTH
TECHNICIAN *K.A.W.* DATE *7/1/59*

achine Data:-
achine No. *T.O.*
ultiplication Factor —
t. Loading Block + Piston (gms.) *21 Kgm.*

Description of Sample: *Native gravel screened to 3" max. Compacted at opt. moisture.*

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure (σ_{III})	Kgm/sq. cm.	0.60					
Length	inches	24½					
Area	sq. cms.	730					
Volume	~~c.c.s.~~ cu. ft.	1.604					
Dry Unit Weight	lbs/cu. ft. γ_d	133.4					
s= · Volume Soil Solids	γ wet	140.3.		Wet Soil	Used	225	lbs.
Wt. Tare + Soil + Water at start							
Wt. Tare + Soil + Water at end		4478					
Wt. Tare + Soil		4269					
Number and weight of Tare		220					
Wt. Soil		4049					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	209					
	Moisture content	5.16					
	Degree of saturation %	53					

Load on Pan	Dial Rdg	Strain	Area	$\sigma_I - \sigma_{III}$	Load on Pan σ_I	Dial Rdg.	Strain	Area	σ_I	Load on Pan	Dial Rdg.	Strain	Area	σ_I
m	ins	%	cm²	Kgm/cm²	Kgm/cm²									
	0.929	-	730	.03	.63									
o	0.918	.04	730	.30	.90									
o	0.895	.14	731	.58	1.18									
o	0.875	.22	731	.85	1.45									
o	0.854	.31	732	1.12	1.72									
00	0.834	.39	733	1.39	1.99									
00	0.811	.48	733	1.67	2.27									
00	0.779	.61	734	1.94	2.54									
00	0.742	.76	735	2.21	2.81									
00	0.681	1.01	737	2.47	3.07									
00	0.635	1.20	738	2.60	3.20									
00	0.568	1.47	741	2.73	3.33									
00	0.480	1.83	743	2.85	3.45									
00	0.120	3.30	755	2.94	3.54									

Failure by bulging.

UNIVERSITY of ALBERTA

DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT	
SITE	
SAMPLE	WINGER PIT - MIXTURE #1
LOCATION	
HOLE	DEPTH
TECHNICIAN K.A.W.	DATE 7/1/59.

achine Data:-
achine No. T.O.
ultiplication Factor —
t. Loading Block + Piston (gms.) 21 Kgm.

Description of Sample:
NATIVE GRAVEL SCREENED TO 3" MAX.
COMPACTED AT OPT. MOISTURE.

SPECIMEN DATA

pecimen Number		1	2	3	4	5	6
ateral Pressure	(σ_{III}) Kgm/sq. cm.	0.90					
ength	inches	24 3/8					
rea	sq. cms.	730					
olume	~~c.c.s.~~ cu. ft.	1.595					
ry Unit Weight	lbs/cu.ft. γ_d	135.3					
s= · Volume Soil Solids	γ_{wet}	142.3		WET SOIL	USED	227	lbs.
Vt. Tare + Soil + Water at start							
Vt. Tare + Soil + Water at end		4673					
Vt. Tare + Soil		4472					
umber and weight of Tare		618					
Vt. Soil		3854					
efore Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	201					
	Moisture content	5.22					
	Degree of saturation %	58					

ad n in	Dial Rdg	Strain	Area	$\sigma_I - \sigma_{III}$	Load on Pan σ_I	Dial Rdg.	Strain	Area	σ_I	Load on Pan	Dial Rdg.	Strain	Area	σ_I
n	ins.	%	cm²	Kgm/cm²	Kgm/cm²									
)	0.945	–	730	·03	·93									
0	0.935	·04	730	·30	1.20									
0	0.918	·11	730	·58	1.48									
0	0.895	·21	731	·85	1.75									
0	0.875	·29	732	1.12	2.02									
0	0.851	·39	732	1.39	2.29									
00	0.829	·48	733	1.67	2.57									
00	0.804	.58	734	1.94	2.84									
00	0.777	·69	735	2.21	3.11									
00	0.744	·83	736	2.48	3.38									
00	0.703	·99	737	2.74	3.64									
00	0.640	1.25	739	3.01	3.91									
00	0.562	1.57	741	3.27	4.17									
00	0.497	1.84	743	3.39	4.29									
00	0.425	2.13	746	3.52	4.42									
00	0.302	2.64	749	3.63	4.53									
60	0.155	3.24	754	3.69	4.59									
00	0.100	3.47	756	3.73	4.63									
						FAILURE BY BULGING.								

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DEPT of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE Winger Pit - Mixture # 1.
LOCATION
HOLE DEPTH
TECHNICIAN K.G.H. DATE 22/1/59

achine Data:-
achine No. T.O.
ultiplication Factor —
t. Loading Block + Piston (gms.) 21 Kgm.

Description of Sample:
Native Gravel Screened to 3" Max.
Compacted at Approx 6.5% Moisture
Felt Liner & Circ. Gauge Used

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure	(~~σm~~) Kgm/sq.cm.	0.30					
Length	inches	24 3/4					
Area	sq. cms.	720					
Volume	~~c.c.s.~~ cu. ft	1.600					
Dry Unit Weight	lbs/cu. ft. γ_d	133.2					
Gs= · Volume Soil Solids	γ_{wet}	141.9		Wet Soil	Used	227	lbs.
Wt. Tare + Soil + Water at start							
Wt. Tare + Soil + Water at end		4263					
Wt. Tare + Soil		4017					
Number and weight of Tare		215					
Wt. Soil		3802					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	246					
	Moisture content	6.48					
	Degree of saturation %	67					

Load on Pan	Dial Rdg	Strain	Area	σ1	Load on Pan	Dial Rdg	Strain	Area	σ1	Load on Pan	Dial Rdg	Strain	Area	σ1
Load	Dial Rdg	Circ Rdg	Strain	ΔC	Area	σ1 − σ3	σ1							
Kgm.	ins.	ins.	%	ins.	cm²	Kgm/cm²	Kgm/cm²							
0	2.952	39 13/16	-	-	720	.03	.33							
0	2.948	"	.02	-	720	.17	.47							
00	2.940	"	.05	-	720	.31	.61							
20	2.924	"	.11	-	720	.45	.75							
00	2.895	39 7/8	.23	1/16	723	.58	.88							
00	2.858	"	.38	1/16	723	.72	1.02							
20	2.809	"	.58	1/16	723	.86	1.16							
0	2.748	39 15/16	.82	1/8	725	.99	1.29							
0	2.670	40 1/16	1.14	1/4	730	1.12	1.42							
0	2.580	40 1/8	1.50	5/16	732	1.26	1.56							
00	2.475	40 1/4	1.93	7/16	738	1.38	1.68							
00	2.315	40 1/2	2.57	11/16	747	1.50	1.80							
00	1.000	40 7/8	7.89	1 1/16	762	1.60	1.90							
00	0.560	41 1/2	9.67	1 11/16	787	1.68	1.98							
80	0.140	42 1/8	11.36	2 5/16	812	1.73	2.03							

Failure by Bulging

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SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT	
SITE	
SAMPLE	WINGER PIT - MIXTURE #1
LOCATION	
HOLE	DEPTH
TECHNICIAN K.U.M.	DATE 22/1/59

lachine Data:–
lachine No. T.O.
lultiplication Factor —
/t. Loading Block + Piston (gms.) 21 Kgm.

Description of Sample:
NATIVE GRAVEL SCREENED TO 1" MAX.
COMPACTED AT APPROX 6.5% MOISTURE
FELT LINER & CIRC GAUGE USED.

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure (σ3) Kgm/sq. cm.		0.60					
Length inches		24 5/8					
Area sq. cms.		720					
Volume ~~c.c.s.~~ cu. ft.		1.591					
Dry Unit Weight lbs/cu.ft. γd		133.3					
Gs= · Volume Soil Solids γwet.		142.0		WET SOIL	USED	226	lbs.
Wt· Tare + Soil + Water at start							
Wt· Tare + Soil + Water at end		4961					
Wt· Tare + Soil		4702					
Number and weight of Tare		691					
Wt· Soil		4011					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	259					
	Moisture content	6.46					
	Degree of saturation %	67					

oad on an	Dial Rdg	Strain	Area	σ1	Load on Pan	Dial Rdg·	Strain	Area	σ1	Load on Pan	Dial Rdg·	Strain	Area	σ1
OAD	DIAL RDG	CIRC. RDG	STRAIN	ΔC	AREA	σ1 - σ111	σ1							
gm.	ins.	ins.	%	ins.	cm²	Kgm/cm²	Kgm/cm²							
0	2.851	39 7/8	-	-	720	.03	.63							
:00	2.837	39 7/8	.06	-	"	.31	.91							
·00	2.800	"	.21	-	"	.58	1.18							
·00	2.750	"	.41	-	"	.86	1.46							
300	2.682	"	.69	-	"	1.14	1.74							
200	2.590	40	1.06	1/8	725	1.41	2.11							
200	2.465	40 1/16	1.57	3/16	728	1.68	2.28							
400	2.303	40 3/16	2.23	5/16	732	1.94	2.54							
600	1.950	40 3/8	3.66	1/2	740	2.19	2.79							
300	1.455	40 5/8	5.67	3/4	750	2.43	3.03							
900	0.950	41 1/8	7.72	1 1/4	769	2.50	3.10							
:000	0.465	41 5/8	9.69	1 3/4	789	2.56	3.16							
.100	- 0.030	42 1/8	11.70	2 1/4	810	2.62	3.22							

FAILURE BY BULGING.

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT	
SITE	
SAMPLE	WINGER PIT - MIXTURE #1
LOCATION	
HOLE	DEPTH
TECHNICIAN K.A.H.	DATE 22/1/59

achine Data:–
achine No. T.O.
ltiplication Factor —
. Loading Block + Piston (gms.) 21 Kgm.

Description of Sample:
NATIVE GRAVEL SCREENED TO 3" MAX
COMPACTED AT APPROX 6.5% MOISTURE.
FELT LINER & CIRC GAUGE USED.

SPECIMEN DATA

pecimen Number		1	2	3	4	5	6
ateral Pressure	(~~σ~~) Kgm./sq.cm.	0.90					
ength	inches	24 5/8					
rea	sq. cms.	720					
olume	~~c.c.s.~~ cu. ft.	1.591					
ry Unit Weight	lbs/cu.ft. γd	137.4					
s= · Volume Soil Solids	γwet	146.3		WET SOIL	USED	233	lbs.
't. Tare + Soil + Water at start							
't. Tare + Soil + Water at end		4513					
't. Tare + Soil		4277					
umber and weight of Tare		618					
't. Soil		3659					
efore Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	236					
	Moisture content	6.45					
	Degree of saturation %	78					

ad n n	Dial Rdg	Strain	Area	σ₁	Load on Pan	Dial Rdg.	Strain	Area	σ₁	Load on Pan	Dial Rdg.	Strain	Area	σ₁
AD	DIAL RDG	CIRC RDG	STRAIN	ΔC	AREA	$\sigma_I - \sigma_{III}$	σ_I							
n	ins.	ins.	%	ins.	cm.²	Kgm/cm²	Kgm/cm²							
	2.862	39 7/8	–	–	720	.03	.93							
0	2.831	"	.13	–	"	.31	1.21							
0	2.759	"	.42	–	"	.58	1.48							
0	2.668	"	.79	–	"	.86	1.76							
0	2.573	39 15/16	1.17	1/16	723	1.14	2.04							
0	2.470	40 1/16	1.59	3/16	728	1.40	2.30							
0	2.360	40 1/8	2.04	1/4	730	1.67	2.57							
0	2.227	40 1/4	2.58	3/8	735	1.93	2.83							
0	1.975	40 3/8	3.60	1/2	740	2.19	3.09							
0	1.775	40 5/8	4.14	3/4	750	2.43	3.33							
0	1.540	40 7/8	5.37	1	759	2.66	3.56							
0	1.410	41 1/16	5.90	1 3/16	767	2.77	3.67							
20	1.234	41 1/4	6.21	1 3/8	774	2.87	3.77							
0	0.800	41 5/8	8.37	1 13/16	792	2.93	3.83							
00	0.500	42	9.59	2 3/16	807	3.00	3.90							

FAILURE BY BULGING.

UNIVERSITY of ALBERTA DEPT. of CIVIL ENGINEERING SOIL MECHANICS LABORATORY **TRI-AXIAL COMPRESSION**	PROJECT SITE SAMPLE *Winger Pit - Mixture #2* LOCATION HOLE DEPTH TECHNICIAN *K. A. W.* DATE *2/1/59*

…achine Data:- …achine No. *T.O.* …ultiplication Factor …t. Loading Block + Piston (gms.) *21 Kgm.*	Description of Sample: *Native Gravel with 4% of -#200 Removed* *Compacted at Optimum Moisture*

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure (σ₃) *Kgm/sq cm*		*0.30*					
Length inches		*24½*					
Area sq. cms.		*730*					
Volume c.c.s. *cu. ft.*		*1.604*					
…ry Unit Weight lbs/cu. ft. *γd*		*130.5*					
…s= ·Volume Soil Solids *γwet*		*136.5*					
…t. Tare + Soil + Water at start							
…t. Tare + Soil + Water at end		*4541*					
…t. Tare + Soil		*4353*		*Wet Soil*	*Used*	*219*	*lbs.*
…umber and weight of Tare		*285*					
…t. Soil		*4068*					
…efore Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	*188*					
	Moisture content	*4.62*					
	Degree of saturation %	*43*					

…ad …n …an	Dial Rdg	Strain	Area	$\sigma_1 - \sigma_{III}$	Load on Pan σ_1
…m	*ins.*	*%*	*cm²*	*Kgm/cm²*	*Kgm/cm²*
…0	*0.967*	–	*730*	*.03*	*.33*
…0	*0.964*	*.01*	"	*.17*	*.47*
…00	*0.956*	*.04*	"	*.30*	*.60*
…0	*0.945*	*.09*	"	*.44*	*.74*
…0	*0.935*	*.13*	*731*	*.58*	*.88*
…0	*0.925*	*.17*	*731*	*.71*	*1.01*
…0	*0.915*	*.21*	*731*	*.85*	*1.15*
…0	*0.905*	*.25*	*732*	*.99*	*1.29*
…0	*0.895*	*.29*	*732*	*1.12*	*1.42*
…00	*0.886*	*.33*	*732*	*1.26*	*1.56*
…00	*0.875*	*.38*	*732*	*1.39*	*1.69*
…00	*0.862*	*.43*	*733*	*1.53*	*1.83*
…00	*0.847*	*.49*	*733*	*1.66*	*1.96*
…00	*0.828*	*.57*	*734*	*1.80*	*2.10*
…00	*0.803*	*.67*	*735*	*1.93*	*2.23*
…0	*0.745*	*.91*	*736*	*2.07*	*2.37*
…80	*0.586*	*1.56*	*741*	*2.16*	*2.46*

Dial Rdg.	Strain	Area	σ₁	Load on Pan	Dial Rdg.	Strain	Area	σ₁

Failure by Bulging

UNIVERSITY of ALBERTA
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SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT	
SITE	
SAMPLE	WINGER PIT - MIXTURE #2
LOCATION	
HOLE	DEPTH
TECHNICIAN	DATE 2/1/59

achine Data:-
achine No. T.O.
ultiplication Factor —
t. Loading Block + Piston (gms.) 21 Kgm.

Description of Sample:
NATIVE GRAVEL WITH 4% OF -#200 REMOVED
COMPACTED AT OPTIMUM MOISTURE

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure	(σ_{III}) Kgm/sq. cm	0.60					
Length	inches	24					
Area	sq. cms.	730					
Volume	c.c.s. cu. ft.	1.571					
Dry Unit Weight	lbs/cu.ft. γ_d	132.0					
Gs= ·Volume Soil Solids	γ_{wet}	138.1		WET SOIL	USED	217	lbs.
Wt. Tare + Soil + Water at start							
Wt. Tare + Soil + Water at end		4375					
Wt. Tare + Soil		4198					
Number and weight of Tare		238					
Wt. Soil		3960					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	177					
	Moisture content	4.57					
	Degree of saturation %	45					

Load on Pan	Dial Rdg	Strain	Area	$\sigma_I - \sigma_{III}$	Load on Pan σ_I	Dial Rdg.	Strain	Area	σ_I	Load on Pan	Dial Rdg.	Strain	Area	σ_I
m.	ins.	%	cm^2	Kgm/cm²	Kgm/cm²									
0	0.951	-	730	.03	.63									
00	0.943	.03	730	.30	.90									
00	0.922	.12	731	.58	1.18									
00	0.903	.20	731	.85	1.45									
00	0.888	.26	732	1.12	1.72									
00	0.874	.32	732	1.40	2.00									
00	0.860	.38	732	1.67	2.27									
00	0.847	.43	733	1.94	2.54									
00	0.834	.49	733	2.21	2.71									
00	0.821	.54	734	2.48	3.08									
00	0.805	.61	734	2.75	3.35									
00	0.781	.71	735	3.02	3.62									
00	0.725	.94	737	3.29	3.89									
00	0.662	1.20	739	3.41	4.01									
90	0.545	1.69	742	3.52	4.12									

FAILURE BY BULGING.

UNIVERSITY of ALBERTA
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SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE *WINGER PIT - MIXTURE #2*
LOCATION
HOLE DEPTH
TECHNICIAN *[illegible]* DATE *2/1/59*

achine Data:-
achine No. *T.O*
ultiplication Factor *-*
t. Loading Block + Piston (gms.) *21 Kgm.*

Description of Sample:
NATIVE GRAVEL WITH 4% OF -#200 REMOVED
COMPACTED AT OPTIMUM MOISTURE

SPECIMEN DATA

pecimen Number		1	2	3	4	5	6
ateral Pressure	(~~σ~~) *Kgm/sq.cm*	*0.90*					
ength	inches	*24 1/16*					
rea	sq. cms.	*730*					
olume	~~c.c.s.~~ *cu.ft.*	*1.575*					
ry Unit Weight	lbs/cu.ft. *γd*	*132.3*					
s= ·Volume Soil Solids	*γwet.*	*138.4*					
/t. Tare + Soil + Water at start							
/t. Tare + Soil + Water at end		*4243*		*WET SOIL*	*USED*	*218*	*lbs*
/t. Tare + Soil		*4070*					
umber and weight of Tare		*238*					
/t. Soil		*3732*					
efore Test	Weight of water						
	Moisture content						
	Degree of saturation						
fter Test	Weight of water	*173*					
	Moisture content	*4.64*					
	Degree of saturation %	*46*					

ad n n	Dial Rdg	Strain	Area	σ1 - σ111	Load on Pan σ1	Dial Rdg.	Strain	Area	σ1	Load on Pan	Dial Rdg.	Strain	Area	σ1
m	*ins*	*%*	*cm²*	*Kgm/cm²*	*Kgm/cm²*									
	0.987	*-*	*730*	*.03*	*.93*									
2	*0.961*	*.11*	*730*	*.58*	*1.48*									
0	*0.936*	*.21*	*731*	*1.12*	*2.02*									
00	*0.914*	*.30*	*732*	*1.67*	*2.57*									
0	*0.892*	*.40*	*733*	*2.21*	*3.11*									
20	*0.866*	*.50*	*733*	*2.76*	*3.66*									
20	*0.852*	*.56*	*734*	*3.03*	*3.93*									
20	*0.833*	*.64*	*734*	*3.30*	*4.20*									
20	*0.814*	*.72*	*735*	*3.57*	*4.47*									
10	*0.784*	*.84*	*736*	*3.83*	*4.73*									
0	*0.737*	*1.04*	*737*	*4.10*	*5.00*									
0	*0.701*	*1.19*	*738*	*4.23*	*5.13*									
0	*0.645*	*1.42*	*740*	*4.35*	*5.25*									
0	*0.560*	*1.77*	*743*	*4.47*	*5.37*									
25	*0.385*	*2.50*	*748*	*4.54*	*5.44*									

FAILURE BY BULGING

UNIVERSITY of ALBERTA
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SOIL MECHANICS LABORATORY
TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE *WINGER PIT · MIXTURE #2*
LOCATION
HOLE DEPTH
TECHNICIAN *K.U.N.* DATE *26/1/59*

achine Data:-
achine No. *T.O.*
ultiplication Factor *—*
t. Loading Block + Piston (gms.) *21 Kgm.*

Description of Sample:
NATIVE GRAVEL WITH 4% OF -#200 REMOVED
COMPACTED AT APPROX. 6% MOISTURE
FELT LINER & CIRC. GAUGE USED

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
ateral Pressure (σ̶) *Kgm./sq. cm.*		0.30					
ength	inches	24 3/8					
rea	sq. cms.	720					
olume	~~c.c.s.~~ *cu. ft.*	1.573					
ry Unit Weight	lbs/cu. ft. γ_d	134.1					
s= ·Volume Soil Solids	γ_{wet}	142.0					
/t. Tare + Soil + Water at start							
/t. Tare + Soil + Water at end		5290					
/t. Tare + Soil		5033		*WET SOIL*	*USED*	*223½*	*lbs.*
umber and weight of Tare		655					
/t. Soil		4378					
efore Test	Weight of water						
	Moisture content						
	Degree of saturation						
fter Test	Weight of water	257					
	Moisture content	5.87					
	Degree of saturation %	62					

ad n n	Dial Rdg	Strain	Area	σ₁	Load on Pan	Dial Rdg.	Strain	Area	σ₁	Load on Pan	Dial Rdg.	Strain	Area	σ₁
AD	*DIAL RDG*	*CIRC. RDG*	*STRAIN*	*ΔC*	*AREA*	*σ₁ - σ₁₁₁*	*σ₁*							
n	*ins.*	*ins.*	*%*	*ins.*	*cm²*	*Kgm/cm²*	*Kgm/cm²*							
	2.969	39 7/8	-	-	720	·03	·33							
0	2.965	"	·02	-	"	·17	·47							
0	2.953	"	·07	-	"	·31	·61							
0	2.932	"	·15	-	"	·45	·75							
0	2.908	"	·25	-	"	·58	·88							
0	2.880	"	·37	-	"	·72	1.02							
0	2.850	39 15/16	·41	1/16	723	·86	1.16							
0	2.818	"	·62	1/16	723	1.00	1.30							
0	2.777	40	·79	1/8	725	1.13	1.43							
0	2.727	40 1/16	·99	3/16	728	1.27	1.57							
0	2.665	40 1/8	1.25	1/4	730	1.40	1.70							
0	2.590	40 1/4	1.56	3/8	735	1.53	1.83							
0	2.485	40 3/8	1.99	1/2	740	1.65	1.95							
0	2.258	40 9/16	2.92	11/16	747	1.77	2.07							
0	1.670	41 7/8	5.33	2	799	1.78	2.08							
20	1.330	42 1/2	6.72	2 5/8	825	1.75	2.05							
						FAILURE	*BY*	*BULGING.*						

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE *WINGER PIT - MIXTURE #2*
LOCATION
HOLE DEPTH
TECHNICIAN *K.W.M.* DATE *26/1/59.*

achine Data:-
achine No. *T.O*
ultiplication Factor *—*
. Loading Block + Piston (gms.) *21 Kgm.*

Description of Sample:
NATIVE GRAVEL WITH 4% OF -#200 REMOVED
COMPACTED AT APPROX 6% MOISTURE
FELT LINER & CIRC GAUGE USED.

SPECIMEN DATA

		1	2	3	4	5	6
pecimen Number		1	2	3	4	5	6
ateral Pressure (σIII) Kgm/sq.cm.		0.60					
ength inches		24 5/8					
rea sq.cms.		720					
olume ~~c.c.s.~~ cu.ft.		1.591					
ry Unit Weight lbs/cu.ft. γ_d		134.9					
s= · Volume Soil Solids γ_{wet}		142.7					
't. Tare + Soil + Water at start							
't. Tare + Soil + Water at end		4398		WET SOIL	USED	227	lbs.
't. Tare + Soil		4187					
umber and weight of Tare		612					
't. Soil		3575					
efore Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	211					
	Moisture content	5.91	.				
	Degree of saturation %	65					

ad n in	Dial Rdg	Strain	Area	σI	Load on Pan	Dial Rdg.	Strain	Area	σI	Load on Pan	Dial Rdg.	Strain	Area	σI
90	DIAL RDG	CIRC RDG	STRAIN	ΔC	AREA	σI - σIII	σI							
n	ins.	ins.	%	ins.	cm²	Kgm/cm²	Kgm/cm²							
)	2.932	39 15/16	-	-	720	.03	.63							
'o	2.918	"	.06	-	"	.31	.91							
)o	2.885	"	.19	-	"	.58	1.18							
'o	2.841	40	.37	1/16	723	.86	1.46							
)o	2.789	"	.58	1/16	723	1.14	1.74							
)o	2.733	40 1/16	.81	1/8	725	1.41	2.01							
)o	2.660	40 1/8	1.11	3/16	728	1.68	2.28							
.00	2.576	40 3/16	1.45	1/4	730	1.95	2.55							
)o	2.450	40 5/16	1.96	3/8	735	2.21	2.81							
oo	2.253	40 5/8	2.76	11/16	747	2.44	3.04							
oo	2.113	40 13/16	3.33	7/8	755	2.55	3.15							
oo	1.820	41 1/4	4.52	1 5/16	772	2.62	3.22							
30	1.530	41 3/4	5.69	1 13/16	792	2.59	3.19							

FAILURE BY BULGING.

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE *WINGER PIT - MIXTURE # 2*
LOCATION
HOLE | DEPTH
TECHNICIAN *K.A.H.* | DATE *26/1/59*

achine Data:-
achine No. *T.O.*
ultiplication Factor
t. Loading Block + Piston (gms.) *21 Kgm.*

Description of Sample:
NATIVE GRAVEL WITH 4% OF - #200 REMOVED
COMPACTED AT APPROX. 6% MOISTURE
FELT LINER & CIRC. GAUGE USED

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure (σ) *Kgm./sq. cm.*		*0.90*					
Length	inches	*24 5/8*					
Area	sq. cms.	*720*					
Volume	~~c.c.s.~~ *cu. ft.*	*1.591*					
Dry Unit Weight	lbs/cu.ft. *γd*	*137.0*					
Gs= · Volume Soil Solids	*γwet*	*145.0*					
Wt. Tare + Soil + Water at start							
Wt. Tare + Soil + Water at end		*4841*		*WET SOIL*	*USED*	*230.5*	*lbs.*
Wt. Tare + Soil		*4606*					
Number and weight of Tare		*646*					
Wt. Soil		*3960*					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	*235*					
	Moisture content	*5.94*					
	Degree of saturation %	*70*					

Load on Pan	Dial Rdg	Strain	Area	σ1	Load on Pan	Dial Rdg.	Strain	Area	σ1	Load on Pan	Dial Rdg.	Strain	Area	σ1
40	*DIAL RDG*	*CIRC RDG*	*STRAIN*	*ΔC*	*AREA*	*σ1 - σIII*	*σ1*							
m	*ins.*	*ins.*	*%*	*ins.*	*cm²*	*Kgm/cm²*	*Kgm/cm²*							
0	*2.990*	*39 15/16*	-	-	*720*	*.03*	*.93*							
00	*2.979*	"	*.05*	-	"	*.31*	*1.21*							
00	*2.956*	"	*.14*	-	"	*.58*	*1.48*							
00	*2.926*	"	*.26*	-	"	*.86*	*1.76*							
00	*2.887*	"	*.42*	-	"	*1.14*	*2.04*							
00	*2.842*	*40*	*.60*	*1/16*	*723*	*1.41*	*2.31*							
00	*2.791*	*40 1/16*	*.81*	*1/8*	*725*	*1.68*	*2.58*							
00	*2.733*	*40 1/8*	*1.04*	*3/16*	*728*	*1.95*	*2.85*							
00	*2.665*	*40 3/16*	*1.32*	*1/4*	*730*	*2.22*	*3.12*							
00	*2.579*	*40 9/32*	*1.67*	*11/32*	*734*	*2.48*	*3.38*							
00	*2.467*	*40 13/32*	*2.12*	*15/32*	*739*	*2.74*	*3.64*							
00	*2.293*	*40 11/16*	*2.83*	*3/4*	*750*	*2.96*	*3.86*							
00	*2.182*	*40 7/8*	*3.28*	*15/16*	*757*	*3.07*	*3.97*							
00	*2.025*	*41 3/16*	*3.92*	*1 1/4*	*769*	*3.15*	*4.05*							
00	*1.845*	*41 13/16*	*4.65*	*1 7/8*	*794*	*3.17*	*4.07*							
00	*1.525*	*42 1/8*	*5.95*	*2 3/16*	*807*	*3.25*	*4.15*							
65	*0.785*	*43 5/8*	*8.95*	*3 11/16*	*869*	*3.09*	*3.99*							
					FAILURE BY BULGING.									

UNIVERSITY of ALBERTA DEPT. of CIVIL ENGINEERING SOIL MECHANICS LABORATORY **TRI-AXIAL COMPRESSION**	PROJECT SITE SAMPLE Winger Pit - Mixture #3 LOCATION HOLE DEPTH TECHNICIAN K.U.H. DATE 9/1/59
achine Data:- achine No. T.O. ultiplication Factor t. Loading Block + Piston (gms.) 21 Kgm	Description of Sample: Native gravel with 6% of -#200 removed Compacted at Optimum Moisture

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
ateral Pressure (σ_{III}) Kgm/sq.cm		0.30					
ength inches		24					
rea sq. cms.		730					
olume ~~c.c.s.~~ cu. ft.		1.572					
ry Unit Weight lbs/cu.ft. γ_d		135.0					
s= · Volume Soil Solids γ_{wet}		141.2					
/t. Tare + Soil + Water at start				Wet Soil	Used	222	lbs.
/t. Tare + Soil + Water at end		4914					
/t. Tare + Soil		4721					
umber and weight of Tare		669					
/t. Soil		4052					
efore Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	193					
	Moisture content	4.76					
	Degree of saturation %	52					

ad n in	Dial Rdg	Strain	Area	$\sigma_I - \sigma_{III}$	Load on Pan	Dial Rdg.	Strain	Area	σ_I	Load on Pan	Dial Rdg.	Strain	Area	σ_I
					σ_I									
m	ins.	%	cm^2	Kgm/cm²	Kgm/cm²									
	0.994	–	730	.03	.33									
0	0.986	.03	730	.17	.47									
0	0.980	.06	730	.30	.60									
0	0.969	.10	731	.44	.74									
0	0.957	.15	731	.58	.88									
0	0.945	.20	731	.71	1.01									
0	0.934	.24	732	.85	1.15									
0	0.921	.29	732	.99	1.29									
0	0.909	.34	732	1.12	1.42									
0	0.897	.39	733	1.26	1.56									
0	0.882	.45	733	1.40	1.70									
0	0.860	.54	734	1.53	1.83									
00	0.832	.65	735	1.66	1.96									
0	0.777	.87	736	1.79	2.09									
75	0.600	1.64	742	1.88	2.18									
						Failure by		Bulging						

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE *Winger Pit · Mixture #3*
LOCATION
HOLE DEPTH
TECHNICIAN *K.U.M.* DATE *9/1/59*

achine Data:-
achine No. *T.O.*
ultiplication Factor
t. Loading Block + Piston (gms.) *21 Kgm.*

Description of Sample:
Native Gravel with 6% of -#200 Removed
Compacted at Optimum Moisture

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure	(σm) Kgm/sq. cm	0.65					
Length	inches	24 3/8					
Area	sq. cms.	730					
Volume	c.c.s. cu. ft.	1.597					
Dry Unit Weight	lbs/cu. ft. γd	133.5					
Gs= · Volume Soil Solids	γwet	139.8					
Wt. Tare + Soil + Water at start							
Wt. Tare + Soil + Water at end		4186					
Wt. Tare + Soil		4005		Wet Soil	Used	223	lbs.
Number and weight of Tare		223					
Wt. Soil		3782					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	181					
	Moisture content	4.79					
	Degree of saturation %	50					

Load on Pan	Dial Rdg	Strain	Area	σ1 − σIII	Load on Pan σ1	Dial Rdg.	Strain	Area	σ1	Load on Pan	Dial Rdg.	Strain	Area	σ1
m	ins.	%	cm²	Kgm/cm²	Kgm/cm²									
)	0.913	-	730	.03	.68									
20	0.905	.03	730	.30	.95									
20	0.891	.09	730	.58	1.23									
00	0.877	.14	731	.85	1.50									
00	0.862	.20	731	1.12	1.77									
00	0.847	.26	732	1.40	2.05									
20	0.829	.34	732	1.67	2.32									
00	0.811	.41	733	1.94	2.59									
00	0.793	.48	733	2.21	2.86									
00	0.767	.58	734	2.48	3.13									
00	0.735	.71	735	2.75	3.40									
.00	0.694	.88	736	3.02	3.67									
20	0.660	1.01	737	3.15	3.80									
00	0.610	1.21	739	3.28	3.93									
20	0.520	1.57	742	3.40	4.05									
90	0.345	2.33	747	3.50	4.15									

Failure by Bulging.

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT	
SITE	
SAMPLE	*Winger Pit - Mixture # 3*
LOCATION	
HOLE	DEPTH
TECHNICIAN *[illegible]*	DATE *9/1/59*

(Ma)chine Data:-
(Ma)chine No. *TC*
(Mu)ltiplication Factor
Loading Block + Piston (gms.) *21 kgm.*

Description of Sample:
Native Gravel with 6% of - #200 Removed
Compacted at Optimum Moisture

SPECIMEN DATA

(S)pecimen Number		1	2	3	4	5	6
(L)ateral Pressure	(σ_{III}) *Kgm/sq. cm.*	*0.90*					
(L)ength	inches	*24*					
(A)rea	sq. cms.	*730*					
(V)olume	c.c.s. - *cu. ft.*	*1.572*					
(D)ry Unit Weight	lbs/cu.ft. γ_d	*139.1*					
= · Volume Soil Solids	γ_{wet}	*145.7*					
(W)t. Tare + Soil + Water at start							-
(W)t. Tare + Soil + Water at end		*4380*					
(W)t. Tare + Soil		*4188*		*Wet Soil*	*Used*	*229*	*lbs.*
(N)umber and weight of Tare		*215*					
(W)t. Soil		*3973*					
(B)efore Test	Weight of water						
	Moisture content						
	Degree of saturation						
(A)fter Test	Weight of water	*192*					
	Moisture content	*4.84*					
	Degree of saturation %	*62*					

(Loa)d (o)n (Pa)n	Dial Rdg	Strain	Area	$\sigma_I - \sigma_{III}$	Load on Pan σ_I	Dial Rdg.	Strain	Area	σ_I	Load on Pan	Dial Rdg.	Strain	Area	σ_I
	ins.	*%*	*cm²*	*Kgm/cm²*	*Kgm/cm²*									
	1.003	-	*730*	*.03*	*.93*									
0	*0.993*	*.04*	*730*	*.44*	*1.34*									
0	*0.976*	*.11*	*731*	*.85*	*1.75*									
0	*0.959*	*.18*	*731*	*1.26*	*2.16*									
0	*0.941*	*.25*	*732*	*1.67*	*2.57*									
0	*0.919*	*.34*	*732*	*2.08*	*2.98*									
0	*0.897*	*.42*	*733*	*2.48*	*3.38*									
0	*0.868*	*.54*	*734*	*2.89*	*3.79*									
0	*0.821*	*.73*	*735*	*3.29*	*4.19*									
0	*0.759*	*.98*	*737*	*3.69*	*4.59*									
0	*0.687*	*1.26*	*739*	*3.96*	*4.86*									
0	*0.632*	*1.48*	*741*	*4.08*	*4.98*									
0	*0.558*	*1.78*	*743*	*4.20*	*5.10*									
0	*0.350*	*2.61*	*750*	*4.28*	*5.18*									

Failure by Bulging.

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE *Winger Pit - Mixture #3*
LOCATION
HOLE DEPTH
TECHNICIAN *K.A.H.* DATE *29/1/59*

achine Data:–
achine No. *T.O.*
ltiplication Factor –
. Loading Block + Piston (gms.) *21 Kgm.*

Description of Sample: *Native gravel with 6% of -#200 removed. Compacted at 6.5% moisture. Felt liner & circ. gauge used.*

SPECIMEN DATA

pecimen Number		1	2	3	4	5	6
ateral Pressure	(~~σ3~~) *Kgm./sq.cm.*	0.30					
ength	inches	24 3/4					
rea	sq. cms.	720					
olume	~~c.c.s.~~ *cu.ft.*	1.600					
ry Unit Weight	lbs/cu.ft. *γd*	136.9					
s= ·Volume Soil Solids	*γwet*	145.7					
't. Tare + Soil + Water at start							
't. Tare + Soil + Water at end		6121		*Wet Soil*	*Used*	*233*	*lbs.*
't. Tare + Soil		5192					
umber and weight of Tare		742					
't. Soil		5050					
efore Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	329					
	Moisture content	6.51					
	Degree of saturation %	77					

ad n in	Dial Rdg	Strain	Area	σ1	Load on Pan	Dial Rdg.	Strain	Area	σ1	Load on Pan	Dial Rdg.	Strain	Area	σ1
AD	*Dial Rdg.*	*Circ. Rdg.*	*Strain*	*ΔC*	*Area*	*σ1 - σ3*	*σ1*							
m.	*ins.*	*ins.*	*%*	*ins.*	*cm²*	*Kgm/cm²*	*Kgm/cm²*							
	2.935	40	–	–	720	.03	.33							
0	2.928	40	.03	–	720	.17	.47							
0	2.894	40	.16	–	720	.31	.61							
0	2.855	40 1/16	.32	1/16	723	.44	.74							
0	2.808	40 1/16	.51	1/16	723	.58	.88							
0	2.761	40 1/8	.70	1/8	725	.72	1.02							
0	2.707	40 1/8	.91	1/8	725	.86	1.16							
0	2.639	40 3/16	1.18	3/16	728	.99	1.29							
0	2.547	40 1/4	1.55	1/4	730	1.12	1.42							
0	2.446	40 3/8	1.96	3/8	735	1.25	1.55							
00	2.327	40 1/2	2.43	1/2	740	1.38	1.68							
00	2.162	40 5/8	3.09	5/8	745	1.51	1.81							
00	1.798	41 1/8	4.55	1 1/8	764	1.60	1.90							
00	0.412	43	10.09	3	840	1.72	2.02							
~~*00*~~														
~~*00*~~						*Failure by*		*Bulging.*						

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
TRI-AXIAL COMPRESSION

PROJECT	
SITE	
SAMPLE	WINGER PIT - MIXTURE #3
LOCATION	
HOLE	DEPTH
TECHNICIAN	R.U.M. DATE 29/1/59

achine Data:-
achine No. TO.
ultiplication Factor -
t. Loading Block + Piston (gms.) 21 Kgm.

Description of Sample:
NATIVE GRAVEL WITH 6% OF -#200 REMOVED
COMPACTED AT 6.5% MOISTURE.
FELT LINER & CIRC. GAUGE USED.

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure	(σIII) Kgm/sq.cm.	0.60					
Length	inches	24 3/4					
Area	sq.cms.	720					
Volume	c.c.s. cu. ft.	1.600					
Dry Unit Weight	lbs/cu.ft. γd	138.0					
Gs= · Volume Soil Solids	γwet	146.9					
Wt. Tare + Soil + Water at start				WET SOIL	USED	235	lbs.
Wt. Tare + Soil + Water at end		7430					
Wt. Tare + Soil		7043					
Number and weight of Tare		896					
Wt. Soil		6147					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	397					
	Moisture content	6.46					
	Degree of saturation %	80					

Load on Pan	Dial Rdg	Strain	Area	σ1	Load on Pan	Dial Rdg.	Strain	Area	σ1	Load on Pan	Dial Rdg.	Strain	Area	σ1
AD	DIAL RDG.	CIRC RDG	% STRAIN	ΔC	AREA	σ1 - σIII	σ1							
m.	ins.	ins.		ins.	cm²	Kgm/cm²	Kgm/cm²							
	2.994	40 5/16	-	-	720	.03	.63							
o	2.968	40 5/16	.10	-	720	.31	.91							
o	2.897	40 3/8	.39	1/16	723	.58	1.18							
o	2.804	40 1/2	.76	3/16	728	.85	1.45							
o	2.700	40 5/8	1.18	5/16	735	1.12	1.72							
o	2.565	40 3/4	1.72	7/16	737	1.38	1.98							
oo	2.426	40 15/16	2.27	5/8	745	1.64	2.24							
·oo	2.251	41 3/16	2.97	7/8	755	1.88	2.48							
oo	2.009	41 9/16	3.94	1 1/4	769	2.11	2.71							
oo	1.640	42 1/8	5.42	1 13/16	787	2.32	2.92							
oo	1.000	43 1/4	7.98	2 15/16	837	2.42	3.02							
oo	0.690	43 3/4	9.22	3 7/16	859	2.47	3.07							
oo	0.200	44 1/2	11.18	4 3/16	891	2.49	3.09							
60	0.000	45	11.98	4 11/16	912	2.50	3.10							

FAILURE BY BULGING.

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
TRI-AXIAL COMPRESSION

PROJECT	
SITE	
SAMPLE	*Winger Pit* *Mixture #3*
LOCATION	
HOLE	DEPTH
TECHNICIAN *[signature]*	DATE *29/1/59*

Machine Data:-

Machine No. *T.O.*

Multiplication Factor *–*

Wt. Loading Block + Piston (gms.) *21 Kgm.*

Description of Sample:

Native gravel with 6% of −#200 removed

Compacted at 6.5% moisture

Felt liner & circ. gauge used

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure	(σ3) *Kgm./sq.cm.*	*0.90*					
Length	inches	*24 3/8*					
Area	sq. cms.	*720*					
Volume	~~c.c.s.~~ *cu. ft.*	*1.573*					
Dry Unit Weight	lbs/cu.ft. *γd*	*138.5*					
Gs= · Volume Soil Solids	*γwet*	*147.4*					
Wt. Tare + Soil + Water at start				*Wet Soil Used*		*232*	*lbs*
Wt. Tare + Soil + Water at end		*5585*					
Wt. Tare + Soil		*5284*					
Number and weight of Tare		*673*					
Wt. Soil		*4611*					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	*301*					
	Moisture content	*6.53*					
	Degree of saturation %	*82*					

Load on Pan	Dial Rdg	Strain	Area	σ1	Load on Pan	Dial Rdg	Strain	Area	σ1	Load on Pan	Dial Rdg	Strain	Area	σ1
Load	*Dial Rdg*	*Circ. Rdg*	*Strain*	*ΔC*	*Area*	*σ1 − σIII*	*σ1*							
gm.	*ins.*	*ins.*	*%*	*ins.*	*cm²*	*Kgm/cm²*	*Kgm/cm²*							
[illegible]	2.963	39 3/4	-	-	720	.03	.93							
70	2.959	39 3/4	.14	-	720	.31	1.21							
20	2.847	39 13/16	.48	1/16	723	.58	1.48							
20	2.745	39 7/8	.90	1/8	725	.86	1.76							
20	2.632	39 31/32	1.36	7/32	729	1.13	2.03							
00	2.502	40 1/8	1.89	3/8	735	1.39	2.29							
00	2.367	40 1/4	2.45	1/2	740	1.65	2.55							
00	2.209	40 3/8	3.09	5/8	745	1.91	2.81							
00	2.048	40 9/16	3.76	13/16	752	2.16	3.06							
00	1.867	40 13/16	4.50	15/16	757	2.40	3.30							
00	1.645	41 1/4	5.41	1 1/2	779	2.60	3.50							
200	1.240	42 3/8	7.08	2 5/8	825	2.69	3.59							
00	0.690	43	9.33	3 1/4	851	2.73	3.63							
400	0.300	43 15/32	10.93	3 23/32	872	2.78	3.68							
80	0.000	44 1/2	12.18	4 3/4	915	2.73	3.63							

Failure by bulging

UNIVERSITY of ALBERTA
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SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE *WINGER PIT - MIXTURE #4*
LOCATION
HOLE DEPTH
TECHNICIAN *K.U.H.* DATE *6/1/59*

lachine Data:–
lachine No. *T.O.*
lultiplication Factor
/t. Loading Block + Piston (gms.) *21 Kgm.*

Description of Sample:
NATIVE GRAVEL CRUSHED TO 2" MAX
COMPACTED AT OPTIMUM MOISTURE.

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure	(σ111) *Kgm/sq. cm.*	*0.30*					
Length	inches	*24 1/2*					
Area	sq. cms.	*730*					
Volume	~~c.c.s.~~ *cu. ft.*	*1.604*					
Dry Unit Weight	lbs/cu. ft. *γd*	*128.4*					
Gs= · Volume Soil Solids	*γwet*	*135.3*					
Wt· Tare + Soil + Water at start							
Wt· Tare + Soil + Water at end		*4395*					
Wt· Tare + Soil		*4184*		*WET SOIL USED*			
Number and weight of Tare		*238*					
Wt· Soil		*3946*					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	*211*					
	Moisture content	*5.35*					
	Degree of saturation %	*47*					

ad on an	Dial Rdg	Strain	Area	σ1 – σ111	~~Load on Pan~~ σ1	Dial Rdg·	Strain	Area	σ1	Load on Pan	Dial Rdg·	Strain	Area	σ1
m	*ins.*	*%*	*cm²*	*Kgm/cm²*	*Kgm/cm²*									
)	*0.934*	*–*	*730*	*·03*	*·33*									
)0	*0.933*	*–*	*730*	*·17*	*·47*									
)0	*0.921*	*·04*	*730*	*·30*	*·60*									
)0	*0.905*	*·12*	*731*	*·44*	*·74*									
)0	*0.887*	*·19*	*731*	*·56*	*·86*									
)0	*0.870*	*·26*	*732*	*·71*	*1.01*									
)0	*0.854*	*·32*	*732*	*·85*	*1.15*									
0	*0.838*	*·38*	*733*	*·98*	*1.28*									
)0	*0.823*	*·44*	*733*	*1.12*	*1.42*									
0	*0.808*	*·50*	*734*	*1.25*	*1.55*									
00	*0.790*	*·58*	*734*	*1.39*	*1.69*									
)0	*0.770*	*·66*	*735*	*1.53*	*1.83*									
00	*0.747*	*·75*	*736*	*1.66*	*1.96*									
20	*0.715*	*·88*	*736*	*1.79*	*2.09*									
00	*0.647*	*1.15*	*738*	*1.92*	*2.22*									
)0	*0.515*	*1.68*	*742*	*2.05*	*2.35*									
40	*0.210*	*2.96*	*752*	*2.08*	*2.38*									
					FAILURE		*BY*	*BULGING.*						

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SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT	
SITE	
SAMPLE	WINGER PIT - MIXTURE #4
LOCATION	
HOLE	DEPTH
TECHNICIAN	DATE 6/1/59

Machine Data:-

achine No. -1:0.

ultiplication Factor —

t. Loading Block + Piston (gms.) 21 Kgm.

Description of Sample:

NATIVE GRAVEL CRUSHED TO 2" MAX

COMPACTED AT OPT MOISTURE

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure	(σ~~m~~) Kgm./sq.cm.	0.60					
Length	inches	24½					
Area	sq. cms.	730					
Volume	~~c.c.s.~~ cu. ft.	1.604					
Dry Unit Weight	lbs/cu.ft. γd	127.0					
Gs= · Volume Soil Solids	γwet	134.0					
Wt. Tare + Soil + Water at start				WET SOIL USED		215	lbs.
Wt. Tare + Soil + Water at end		5135					
Wt. Tare + Soil		4912					
Number and weight of Tare		774					
Wt. Soil		4138					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	223					
	Moisture content	5.40					
	Degree of saturation %	45					

Load on Pan	Dial Rdg	Strain	Area	σI − σIII	Load on Pan σI	Dial Rdg.	Strain	Area	σI	Load on Pan	Dial Rdg.	Strain	Area	σI
gm	ins.	%	cm²	Kgm/cm²	Kgm/cm²									
0	0.928	–	730	.03	.63									
00	0.921	.03	730	.30	.90									
00	0.903	.07	731	.58	1.18									
00	0.882	.18	731	.85	1.45									
00	0.867	.24	732	1.12	1.72									
00	0.848	.32	732	1.39	1.99									
200	0.830	.39	733	1.67	2.27									
400	0.809	.48	734	1.94	2.54									
00	0.780	.59	734	2.21	2.81									
300	0.737	.76	736	2.47	3.07									
00	0.658	1.08	738	2.74	3.34									
00	0.593	1.34	740	2.87	3.47									
200	0.495	1.73	743	2.99	3.59									
300	0.267	2.64	750	3.09	3.69									
350	-0.010	3.83	759	3.13	3.73									

FAILURE BY BULGING.

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SOIL MECHANICS LABORATORY
TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE Winger Pit - Mixture # 4
LOCATION
HOLE — DEPTH
TECHNICIAN [illegible] DATE [illegible]

achine Data:–
achine No. T.O.
ultiplication Factor —
t. Loading Block + Piston (gms.) 21 Kgm.

Description of Sample:
Native Gravel Crushed to 2" Max
Compacted at Optimum Moisture

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure (σ_{III}) Kgm/sq.cm.		0.90					
Length inches		22 1/2					
Area sq. cms.		730					
Volume c.c.s. cu. ft.		1.473					
Dry Unit Weight lbs/cu.ft. γ_d		130.1					
Gs= · Volume Soil Solids γ_{wet}		137.2					
Wt. Tare + Soil + Water at start							
Wt. Tare + Soil + Water at end		4076		Wet Soil	Used	202	lbs.
Wt. Tare + Soil		3905					
Number and weight of Tare		773					
Wt. Soil		3132					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	171					
	Moisture content	5.46					
	Degree of saturation %	50					

Load on Pan	Dial Rdg	Strain	Area	$\sigma_I - \sigma_{III}$	Load on Pan σ_I	Dial Rdg.	Strain	Area	σ_I	Load on Pan	Dial Rdg.	Strain	Area	σ_I
m.	ins.	%	cm²	Kgm/cm²	Kgm/cm²									
0	1.994	–	730	.03	.93									
00	1.976	.07	731	.30	1.20									
20	1.952	.17	731	.58	1.48									
20	1.923	.28	732	.85	1.75									
20	1.901	.37	733	1.12	2.02									
00	1.877	.47	733	1.39	2.29									
00	1.852	.57	734	1.66	2.56									
00	1.829	.66	735	1.93	2.83									
00	1.806	.75	736	2.20	3.10									
00	1.776	.87	736	2.47	3.37									
00	1.742	1.01	737	2.74	3.64									
200	1.706	1.15	738	3.01	3.91									
400	1.649	1.38	740	3.27	4.17									
600	1.577	1.67	742	3.53	4.43									
700	1.513	1.92	744	3.66	4.56									
300	1.425	2.28	747	3.78	4.68									
900	1.285	2.84	751	3.89	4.79									
00	1.120	3.50	756	4.00	4.90									
00	0.923	4.28	763	4.09	4.99									
67	0.657	5.94	776	4.11	5.01									
						Failure by Bulging.								

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SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE *Winger Pit · Mixture #4*
LOCATION
HOLE DEPTH
TECHNICIAN *R.A.W.* DATE *23/1/59*

Machine Data:-
Machine No. *T.O.*
Multiplication Factor —
Wt. Loading Block + Piston (gms.) *21 Kgm.*

Description of Sample:
Native gravel crushed to 2" max.
Compacted at approx. 6.5% moisture
Felt liner & circ gauge used.

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure	(~~σIII~~) *Kgm./sq.cm.*	*0.30*					
Length	inches	*24 13/16*					
Area	sq. cms.	*720*					
Volume	~~c.c.s.~~ *cu. ft.*	*1.602*					
Dry Unit Weight	lbs/cu.ft. *γd*	*123.7*					
Gs= · Volume Soil Solids	*γwet*	*131.2*					
Wt. Tare + Soil + Water at start				*Wet Soil*	*Used*	*210½*	*lbs.*
Wt. Tare + Soil + Water at end		*6494*					
Wt. Tare + Soil		*6167*					
Number and weight of Tare		*782*					
Wt. Soil		*5385*					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	*327*					
	Moisture content	*6.08*					
	Degree of saturation %	*46*					

Load on Pan	Dial Rdg	Strain	Area	σ1	Load on Pan	Dial Rdg.	Strain	Area	σ1	Load on Pan	Dial Rdg.	Strain	Area	σ1
Load	*Dial Rdg*	*Circ Rdg.*	*Strain*	*ΔC*	*Area*	*σ1 - σIII*	*σ1*							
Kgm.	*ins.*	*ins.*	*%*	*ins.*	*cm.²*	*Kgm/cm²*	*Kgm/cm²*							
2	*2.960*	*39¾*	–	–	*720*	*.03*	*.33*							
00	*2.957*	"	*.01*	–	"	*.17*	*.47*							
00	*2.952*	"	*.03*	–	"	*.31*	*.61*							
00	*2.940*	"	*.08*	–	"	*.45*	*.75*							
00	*2.926*	"	*.14*	–	"	*.58*	*.88*							
00	*2.909*	"	*.20*	–	"	*.72*	*1.02*							
00	*2.889*	"	*.28*	–	"	*.86*	*1.16*							
00	*2.865*	"	*.38*	–	"	*1.00*	*1.30*							
20	*2.833*	"	*.51*	–	"	*1.14*	*1.44*							
0	*2.789*	*39 13/16*	*.68*	*1/16*	*723*	*1.27*	*1.57*							
00	*2.732*	*39 7/8*	*.91*	*1/8*	*725*	*1.41*	*1.71*							
00	*2.638*	*40*	*1.29*	*1/4*	*730*	*1.54*	*1.84*							
00	*2.489*	*40 1/4*	*1.88*	*1/2*	*740*	*1.65*	*1.95*							
00	*2.157*	*40 3/4*	*3.24*	*1*	*759*	*1.74*	*2.04*							
40	*1.755*	*41 1/2*	*4.82*	*1 3/4*	*789*	*1.72*	*2.02*							
00	*0.920*	*42 3/4*	*8.16*	*3*	*840*	*1.69*	*1.99*							

Failure by bulging

UNIVERSITY of ALBERTA
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SOIL MECHANICS LABORATORY
TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE Winger Pit - Mixture #4
LOCATION
HOLE DEPTH
TECHNICIAN K.U.M. DATE 23/1/59

Machine Data:-
Machine No. T.O.
Multiplication Factor —
Wt. Loading Block + Piston (gms.) 21 Kgm.

Description of Sample:
Native gravel crushed to 2" max.
Compacted at approx 6.5% moisture
Felt liner & circ gauge used.

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure (σ3) Kgm./sq. cm		0.60					
Length	inches	24 5/8					
Area	sq. cms.	720					
Volume	~~c.c.s.~~ cu. ft.	1.591					
Dry Unit Weight	lbs/cu. ft. γd	124.6					
Gs= · Volume Soil Solids	γwet	132.2					
Wt. Tare + Soil + Water at start							
Wt. Tare + Soil + Water at end		5043		Wet Soil	Used	211	lbs.
Wt. Tare + Soil		4788					
Number and weight of Tare		625					
Wt. Soil		4163					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	255					
	Moisture content	6.13					
	Degree of saturation %	47					

Load on Pan	Dial Rdg	Strain	Area	σ1	Load on Pan	Dial Rdg.	Strain	Area	σ1	Load on Pan	Dial Rdg.	Strain	Area	σ1
Load	Dial Rdg	Circ. Rdg	Strain	ΔC	Area	σ1 - σ3	σ1							
Kgm.	ins.	ins.	%	ins.	cm²	Kgm/cm²	Kgm/cm²							
0	2.965	39 7/8	–	–	720	.03	.63							
200	2.950	39 7/8	.06	–	"	.31	.91							
400	2.932	39 7/8	.13	–	"	.58	1.18							
600	2.908	39 7/8	.23	–	"	.86	1.46							
800	2.877	39 7/8	.35	–	"	1.14	1.74							
1000	2.837	39 7/8	.51	–	"	1.42	2.02							
1200	2.779	39 15/16	.74	1/16	723	1.69	2.29							
1400	2.693	40 1/16	1.09	3/16	728	1.95	2.55							
1600	2.555	40 1/4	1.64	3/8	735	2.21	2.81							
1800	2.288	40 5/8	2.71	3/4	750	2.43	3.03							
1900	2.047	41 1/16	3.67	1 3/16	767	2.51	3.11							
2000	1.600	41 1/2	5.46	1 5/8	784	2.58	3.18							
2100	1.190	42 1/2	7.10	2 5/8	825	2.57	3.17							
2140	0.900	43	8.26	3 1/8	846	2.56	3.16							

Failure by bulging

UNIVERSITY of ALBERTA
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SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE *Winger Pit - Mixture #4*
LOCATION
HOLE DEPTH
TECHNICIAN *K. A. L.* DATE *23/1/59*

Machine Data:-
Machine No. *T.O.*
Multiplication Factor —
Wt. Loading Block + Piston (gms.) *21 Kgm*

Description of Sample:
Native gravel crushed to 2" max.
Compacted at approx 6.5% moisture
Felt liner & circ. gauge used.

SPECIMEN DATA

Specimen Number	1	2	3	4	5	6
Lateral Pressure (σ_{III}) Kgm/sq. cm.	0.40					
Length inches	$24\frac{5}{8}$					
Area sq. cms.	720					
Volume ~~c.c.s.~~ cu. ft.	1.591					
Dry Unit Weight lbs/cu. ft. γ_d	129.3					
Gs= ·Volume Soil Solids γ_{wet}	137.2					
Wt. Tare + Soil + Water at start						
Wt. Tare + Soil + Water at end	5638		Wet soil used	219 lbs.		
Wt. Tare + Soil	5351					
Number and weight of Tare	671					
Wt. Soil	4680					
Before Test — Weight of water						
Before Test — Moisture content						
Before Test — Degree of saturation						
After Test — Weight of water	287					
After Test — Moisture content	6.14					
After Test — Degree of saturation %	55					

Load on Pan	Dial Rdg	Strain	Area	σ_1	Load on Pan	Dial Rdg.	Strain	Area	σ_1	Load on Pan	Dial Rdg.	Strain	Area	σ_1
Load	Dial Rdg	Circ Rdg	Strain	ΔC	Area	$\sigma_1 - \sigma_{III}$	σ_1							
Kgm.	ins.	ins.	%	ins.	cm²	Kgm/cm²	Kgm/cm²							
0	2.926	$39\frac{7}{8}$	–	–	720	.03	.93							
00	2.905	$39\frac{7}{8}$	.08	–	720	.45	1.35							
00	2.876	$39\frac{7}{8}$	.20	–	720	.86	1.76							
00	2.835	$39\frac{15}{16}$	.36	1/16	723	1.27	2.17							
200	2.776	$39\frac{15}{16}$	.60	1/16	723	1.69	2.59							
500	2.690	40	.94	1/8	726	2.10	3.00							
800	2.567	$40\frac{1}{8}$	1.44	1/4	730	2.49	3.39							
100	2.373	$40\frac{3}{8}$	2.21	1/2	740	2.87	3.77							
400	2.055	$40\frac{3}{4}$	3.48	7/8	754	3.21	4.11							
600	1.710	$41\frac{1}{4}$	4.86	$1\frac{3}{8}$	774	3.38	4.28							
700	1.460	$41\frac{5}{8}$	5.86	$1\frac{3}{4}$	789	3.45	4.35							
800	1.160	$41\frac{7}{8}$	7.06	2	799	3.53	4.43							
900	0.765	43	8.64	$3\frac{1}{8}$	846	3.45	4.35							
000	0.210	44	10.86	$4\frac{1}{8}$	888	3.40	4.30							

Failure by bulging.

UNIVERSITY of ALBERTA
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SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE WINGER PIT - MIXTURE #5
LOCATION
HOLE DEPTH
TECHNICIAN [illegible] DATE 30/12/58

Machine Data:-
Machine No. T.O.
Multiplication Factor —
Wt. Loading Block + Piston (gms.) 21 Kgm.

Description of Sample:
NATIVE GRAVEL CRUSHED TO 1½" MAX.
COMPACTED AT OPTIMUM
MOISTURE CONTENT.

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure	(σ_{III}) Kgm/sq. cm.	0.30					
Length	inches	23 3/4					
Area	sq. cms.	730					
Volume	~~c.c.s.~~ cu. ft.	1.554					
Dry Unit Weight	lbs/cu. ft. γ_d	130.9					
Gs= · Volume Soil Solids	γ_{wet}	137.7					
Wt. Tare + Soil + Water at start							
Wt. Tare + Soil + Water at end		6925					
Wt. Tare + Soil		6616		WET SOIL USED		214	lbs.
Number and weight of Tare		688					
Wt. Soil		5928					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	309					
	Moisture content	5.21					
	Degree of saturation %	49					

Load on Pan	Dial Rdg	Strain	Area	$\sigma_I - \sigma_{III}$	Load on Pan σ_I	Dial Rdg.	Strain	Area	σ_I	Load on Pan	Dial Rdg.	Strain	Area	σ_I
Kgm.	ins	%	cm²	Kgm/cm²	Kgm/cm²									
0	0.975	—	730	.03	.33									
100	0.947	.12	731	.17	.47									
200	0.927	.20	731	.30	.60									
300	0.910	.27	732	.44	~~1.04~~ .74									
400	0.894	.34	732	.58	~~1~~ .88									
500	0.879	.40	733	.71	1.01									
600	0.863	.47	733	.85	1.15									
700	0.849	.53	734	.98	1.28									
800	0.832	.60	734	1.12	1.42									
900	0.815	.67	735	1.25	1.55									
1000	0.793	.77	735	1.39	1.69									
1100	0.767	.88	736	1.52	1.82									
1200	0.736	1.01	737	1.66	1.96									
1300	0.686	1.22	739	1.79	2.09									
1400	0.590	1.62	742	1.92	2.22									
1490	0.220	3.18	754	2.00	2.30									

FAILURE BY BULGING.

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE *Winger Pit - Mixture #5*
LOCATION
HOLE *1* DEPTH
TECHNICIAN *S.A.L.* DATE *30/12/58*

Machine Data:-
Machine No. *T.O.*
Multiplication Factor
Wt. Loading Block + Piston (gms.) *21 Kgm*

Description of Sample: *Native gravel crushed to 1½" max. Compacted at optimum moisture content*

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure	(σ_{III}) *Kgm/sq. cm.*	0.60					
Length	inches	23½					
Area	sq. cms.	730					
Volume	c.c.s.	1.538					
Dry Unit Weight	lbs/cu.ft. γ_d	131.6					
Gs= ·Volume Soil Solids	γ_{wet}	138.5					
Wt. Tare + Soil + Water at start							
Wt. Tare + Soil + Water at end		8010		Wet Soil Used		213	lbs.
Wt. Tare + Soil		7657					
Number and weight of Tare		829					
Wt. Soil		6828					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	353					
	Moisture content	5.17					
	Degree of saturation %	50					

Load on Pan	Dial Rdg	Strain	Area	$\sigma_1 - \sigma_{III}$	Load on Pan σ_1	Dial Rdg.	Strain	Area	σ_1	Load on Pan	Dial Rdg.	Strain	Area	σ_1
gm.	ins.	%	cm.²	Kgm/cm.²	Kgm/cm²									
0	1.934	–	730	.03	.63									
200	1.896	.16	731	.30	.90									
200	1.873	.26	732	.58	1.18									
600	1.850	.36	732	.85	1.45									
300	1.829	.45	733	1.12	1.72									
200	1.808	.54	734	1.39	1.99									
200	1.785	.63	734	1.66	2.26									
400	1.758	.75	735	1.93	2.56									
600	1.723	.90	736	2.20	2.80									
800	1.667	1.14	738	2.47	3.07									
000	1.573	1.54	741	2.73	3.33									
100	1.496	1.86	744	2.85	3.45									
200	1.380	2.36	747	2.97	3.57									
300	1.145	3.36	755	3.07	3.67									
415	0.709	5.21	770	3.16	3.76									

UNIVERSITY of ALBERTA
DEPT of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE *Winger Pit . Mixture #5*
LOCATION
HOLE [illegible] DEPTH
TECHNICIAN [illegible] DATE *30/12/58*

Machine Data:-
Machine No. *T.O*
Multiplication Factor *-*
Wt. Loading Block + Piston (gms) *21 Kgm.*

Description of Sample: *Native Gravel Crushed to 1½" Max. Compacted at Optimum Moisture Content.*

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure (σ_{III}) Kgm/sq. cm.		0.90					
Length inches		22 7/8					
Area sq. cms.		730					
Volume ~~c.c.s.~~ cu. ft.		1.497					
Dry Unit Weight lbs/cu. ft. γ_d		123.1					
Gs= · Volume Soil Solids γ_{wet}		129.5					
Wt. Tare + Soil + Water at start							
Wt. Tare + Soil + Water at end		9371		WET SOIL USED		193	lbs.
Wt. Tare + Soil		8950					
Number and weight of Tare		772					
Wt. Soil		8178					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	421					
	Moisture content	5.15					
	Degree of saturation %	38					

Load on Pan	Dial Rdg	Strain	Area	$\sigma_1 - \sigma_{III}$	Load on Pan (σ_1)	Dial Rdg	Strain	Area	σ_1	Load on Pan	Dial Rdg	Strain	Area	σ_1
Kgm	ins	%	cm²	Kgm/cm²	Kgm/cm²									
0	1.762	-	730	.03	.93									
300	1.741	.09	730	.44	1.34									
600	1.721	.18	731	.85	1.75									
900	1.699	.28	732	1.26	2.16									
200	1.677	.37	732	1.67	2.57									
500	1.654	.47	733	2.08	2.98									
800	1.628	.59	734	2.48	3.38									
100	1.597	.72	735	2.89	3.79									
400	1.555	.91	736	3.29	4.19									
700	1.492	1.18	738	3.69	4.59									
000	1.390	1.63	742	4.07	4.97									
100	1.340	1.85	743	4.20	5.10									
200	1.263	2.18	746	4.32	5.22									
300	1.135	2.74	750	4.43	5.33									
400	0.970	3.46	756	4.53	5.43									
470	0.735	4.49	764	4.57	5.47									

Failure by Bulging.

UNIVERSITY of ALBERTA DEPT. of CIVIL ENGINEERING SOIL MECHANICS LABORATORY **TRI-AXIAL COMPRESSION**	PROJECT SITE SAMPLE *Winger Pit - Mixture #5* LOCATION HOLE DEPTH TECHNICIAN *K.A.M.* DATE *15/1/59*

Machine Data:-
Machine No. *T.O.*
Multiplication Factor *—*
Wt. Loading Block + Piston (gms.) *21 Kgm*

Description of Sample:
Native gravel crushed to 1½" max.
Compacted at approx. 6.5% moisture
Felt liner & circ. gauge used

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure	(~~σm~~) *Kgm./sq. cm.*	*0.30*					
Length	inches	*24 ¾*					
Area	sq. cms.	*720*					
Volume	~~c.c.s.~~ *cu. ft.*	*1.600*					
Dry Unit Weight	lbs/cu. ft. *γd*	*135.5*					
Gs = · Volume Soil Solids	*γwet*	*144.2*					
Wt. Tare + Soil + Water at start							
Wt. Tare + Soil + Water at end		*6879*					
Wt. Tare + Soil		*6514*		*Wet Soil Used*		*230.5*	*lbs.*
Number and weight of Tare		*821*					
Wt. Soil		*5693*					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	*365*					
	Moisture content	*6.41*					
	Degree of saturation %	*72*					

Load on Pan	Dial Rdg	Strain	Area	σ1	Load on Pan	Dial Rdg.	Strain	Area	σ1	Load on Pan	Dial Rdg.	Strain	Area	σ1
Load	*Dial Rdg*	*Circ Rdg*	*Strain*	*ΔC*	*Area*	*σ1 - σIII*	*σ1*							
Kgm.	*ins.*	*ins.*	*%*	*ins.*	*cm²*	*Kgm/cm²*	*Kgm/cm²*							
0	*2.927*	*39 7/8*	*–*	*–*	*720*	*.03*	*.33*							
100	*2.918*	*39 7/8*	*.04*	*–*	*720*	*.17*	*.47*							
200	*2.901*	*39 15/16*	*.11*	*1/16*	*723*	*.31*	*.61*							
300	*2.872*	*39 15/16*	*.22*	*1/16*	*723*	*.44*	*.74*							
400	*2.835*	*39 15/16*	*.37*	*1/16*	*723*	*.58*	*.88*							
500	*2.789*	*40*	*.56*	*1/8*	*725*	*.72*	*1.02*							
600	*2.734*	*40 1/16*	*.78*	*3/16*	*728*	*.85*	*1.15*							
700	*2.669*	*40 1/8*	*1.04*	*1/4*	*730*	*.99*	*1.29*							
800	*2.586*	*40 1/4*	*1.38*	*3/8*	*735*	*1.12*	*1.42*							
900	*2.497*	*40 3/8*	*1.74*	*1/2*	*740*	*1.25*	*1.55*							
000	*2.369*	*40 9/16*	*2.26*	*11/16*	*747*	*1.37*	*1.67*							
100	*2.194*	*40 11/16*	*2.96*	*13/16*	*752*	*1.49*	*1.79*							
200	*1.962*	*40 7/8*	*3.90*	*1*	*765*	*1.60*	*1.90*							
300	*1.390*	*42*	*6.21*	*2 1/8*	*804*	*1.64*	*1.94*							
400	*0.730*	*43 3/8*	*8.88*	*3 1/2*	*861*	*1.65*	*1.95*							
500	*0.140*	*44 3/8*	*11.26*	*4 1/2*	*904*	*1.68*	*1.98*							

Failure by bulging.

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT	
SITE	
SAMPLE	WINGER PIT - MIXTURE #5
LOCATION	
HOLE	DEPTH
TECHNICIAN R.A.M.	DATE 15/1/59

Machine Data:-
Machine No. T.O.
Multiplication Factor —
Wt. Loading Block + Piston (gms.) 21 Kgm

Description of Sample:
NATIVE GRAVEL CRUSHED TO 1½" MAX.
COMPACTED AT APPROX. 6.5% M.C.
FELT LINER & CIRC. GAUGE USED

SPECIMEN DATA

Specimen Number			1	2	3	4	5	6
Lateral Pressure		(σ_3) Kgm/sq. cm	0.60					
Length		inches	24½					
Area		sq. cms.	720					
Volume		~~c.c.s.~~ cu. ft.	1.581					
Dry Unit Weight		lbs/cu.ft. γ_d	137.2					
Gs= · Volume Soil Solids		γ_{wet}	146.0					
Wt. Tare + Soil + Water at start								
Wt. Tare + Soil + Water at end			7791					
Wt. Tare + Soil			7379		WET SOIL USED		231	lbs.
Number and weight of Tare			912					
Wt. Soil			6467					
Before Test	Weight of water							
	Moisture content							
	Degree of saturation							
After Test	Weight of water		412					
	Moisture content		6.37					
	Degree of saturation %		76					

Load on Pan	Dial Rdg	Strain	Area	σ_1	Load on Pan	Dial Rdg	Strain	Area	σ_1	Load on Pan	Dial Rdg	Strain	Area	σ_1
LOAD	DIAL RDG	CIRC RDG	STRAIN	ΔC	AREA	$\sigma_1 - \sigma_{III}$	σ_1							
Kgm	ins.	ins.	%	ins.	cm²	Kgm/cm²	Kgm/cm²							
0	2.986	39⅞	–	–	720	.03	.63							
200	2.965	40	.09	⅛	725	.31	.91							
400	2.921	40 1/16	.27	3/16	728	.58	1.18							
600	2.853	40 1/16	.54	3/16	728	.85	1.45							
800	2.762	40 3/16	.91	5/16	732	1.12	1.72							
000	2.657	40 3/16	1.34	5/16	732	1.39	1.99							
200	2.526	40 ¼	1.88	⅜	735	1.66	2.26							
400	2.359	40 ½	2.15	⅝	745	1.91	2.51							
600	2.130	40 11/16	3.49	13/16	752	2.16	2.76							
800	1.846	41 3/16	4.65	1 5/16	772	2.36	2.96							
900	1.633	41 ½	5.52	1 ⅝	784	2.45	3.05							
000	1.350	41 ⅞	6.68	2	799	2.53	3.13							
100	0.825	43	8.82	3 ⅛	846	2.51	3.11							
190	0.020	44	12.11	4 ⅛	888	2.49	3.09							
						FAILURE BY	BULGING.							

UNIVERSITY of ALBERTA

DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT	
SITE	
SAMPLE	*Winger Pit - Mixture #5*
LOCATION	
HOLE	DEPTH
TECHNICIAN *B. C. H.*	DATE *15/1/59*

Machine Data:–

Machine No. *T.O.*

Multiplication Factor –

Wt. Loading Block + Piston (gms.) *21 Kgm.*

Description of Sample:

Native gravel crushed to 1½" max
Compacted at approx 6.5% moisture
Felt liner & circ. gauge used

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure (σ_{III}) *Kgm/sq.cm.*		*0.90*					
Length	inches	*24½*					
Area	sq. cms.	*720*					
Volume	~~c.c.s.~~ *cu. ft.*	*1.567*					
Dry Unit Weight	lbs/cu. ft. *γ_d*	*136.8*					
Gs = · Volume Soil Solids *γ_{wet}*		*145.7*					
Wt. Tare + Soil + Water at start				*Wet Soil Used*		*228*	*lbs.*
Wt. Tare + Soil + Water at end		*5731*					
Wt. Tare + Soil		*5424*					
Number and weight of Tare		*616*					
Wt. Soil		*4808*					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	*307*					
	Moisture content	*6.39*					
	Degree of saturation %	*75*					

Load on Pan	Dial Rdg	Strain	Area	σ_1	Load on Pan	Dial Rdg.	Strain	Area	σ_1	Load on Pan	Dial Rdg.	Strain	Area	σ_1
Load	*Dial Rdg*	*Circ. Rdg*	*Strain*	*ΔC*	*Area*	*$\sigma_1 - \sigma_{III}$*	*σ_1*							
Kgm.	*ins.*	*ins.*	*%*	*ins.*	*cm²*	*Kgm/cm²*	*Kgm/cm²*							
0	*2.965*	*39 7/8*	–	–	*720*	*.03*	*.93*							
300	*2.936*	*39 15/16*	*.12*	*1/16*	*723*	*.44*	*1.34*							
600	*2.864*	*40*	*.42*	*1/8*	*725*	*.86*	*1.76*							
900	*2.761*	*40 1/16*	*.84*	*3/16*	*728*	*1.27*	*2.17*							
1200	*2.640*	*40 1/8*	*1.34*	*1/4*	*730*	*1.67*	*2.57*							
1500	*2.410*	*40 5/16*	*2.29*	*7/16*	*737*	*2.06*	*2.96*							
1800	*2.245*	*40 1/2*	*2.97*	*5/8*	*745*	*2.45*	*3.35*							
2100	*1.930*	*40 7/8*	*4.27*	*1*	*759*	*2.79*	*3.69*							
2300	*1.840*	*41 3/16*	*4.64*	*1 5/16*	*772*	*3.01*	*3.91*							
2400	*1.670*	*41 3/8*	*5.34*	*1 1/2*	*779*	*3.12*	*4.02*							
2600	*1.500*	*41 13/16*	*6.04*	*1 15/16*	*797*	*3.29*	*4.19*							
2700	*1.290*	*42 1/16*	*6.91*	*2 3/16*	*807*	*3.37*	*4.27*							
2900	*0.990*	*42 1/2*	*8.14*	*2 5/8*	*825*	*3.54*	*4.44*							
3100	*0.000*	*44 1/8*	*12.23*	*4 1/4*	*893*	*3.49*	*4.39*							

Failure by bulging.

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE Winger Pit - Mixture #6
LOCATION
HOLE DEPTH
TECHNICIAN R. U. H. DATE 27/1/59

Machine Data:-
Machine No. T.O
Multiplication Factor
Wt. Loading Block + Piston (gms.) 21 Kgm.

Description of Sample:
Native gravel crushed to 1" max.
Compacted at opt. moist. content
Felt liner used

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure (σ_3) Kgm/sq.cm.		0.30					
Length inches		24 1/2					
Area sq. cms.		720					
Volume ~~c.c.s.~~ cu. ft.		1.581					
Dry Unit Weight lbs/cu.ft. γ_d		124.5					
Gs= ·Volume Soil Solids γ_{wet}		131.0					
Wt. Tare + Soil + Water at start							
Wt. Tare + Soil + Water at end		8249		Wet Soil Used 207 lbs.			
Wt. Tare + Soil		7887					
Number and weight of Tare		856					
Wt. Soil		7031					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	362					
	Moisture content	5.15					
	Degree of saturation %	40					

Load on Pan	Dial Rdg	Strain	Area	$\sigma_1 - \sigma_{III}$	Load on Pan σ_1	Dial Rdg.	Strain	Area	σ_1	Load on Pan	Dial Rdg.	Strain	Area	σ_1
Kgm	ins	%	cm²	Kgm/cm²	Kgm/cm²									
0	2.968	-	720	.03	.33									
100	2.958	.01	721	.17	.47									
200	2.952	.02	721	.31	.61									
300	2.942	.03	721	.44	.74									
400	2.928	.04	722	.58	.88									
500	2.915	.05	722	.72	1.02									
600	2.900	.07	722	.86	1.16									
700	2.884	.08	723	1.00	1.30									
800	2.867	.10	723	1.14	1.44									
900	2.848	.12	724	1.27	1.57									
1000	2.824	.14	725	1.41	1.71									
1100	2.791	.18	726	1.54	1.84									
1200	2.737	.23	727	1.68	1.98									
1300	2.643	.32	730	1.81	2.11									
1400	2.400	.57	738	1.93	2.23									
1450	1.880	1.09	754	1.95	2.25									
					Failure by bulging									

UNIVERSITY of ALBERTA
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SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE Winger Pit - Mixture #6
LOCATION
HOLE DEPTH
TECHNICIAN K.T.W. DATE 27/1/59

Machine Data:-
Machine No. T.O.
Multiplication Factor -
Wt. Loading Block + Piston (gms.) 21 Kgm.

Description of Sample:
NATIVE GRAVEL CRUSHED TO 1" MAX
COMPACTED AT OPT. M. C.
FELT LINER USED

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure (σ_{III}) Kgm./sq. cm.		0.60					
Length inches		24 3/8					
Area sq. cms.		720					
Volume ~~c.c.s.~~ cu. ft.		1.573					
Dry Unit Weight lbs/cu.ft. γ_d		129.8					
Gs= ·Volume Soil Solids γ_{wet}		136.6					
Wt. Tare + Soil + Water at start				WET SOIL USED 215 lbs.			
Wt. Tare + Soil + Water at end		9455					
Wt. Tare + Soil		9033					
Number and weight of Tare		919					
Wt. Soil		8114					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	422					
	Moisture content	5.20					
	Degree of saturation %	47					

Load on Pan	Dial Rdg	Strain	Area	$\sigma_1 - \sigma_{III}$	Load on Pan σ_1	Dial Rdg	Strain	Area	σ_1	Load on Pan	Dial Rdg	Strain	Area	σ_1
Kgm	ins	%	cm²	Kgm/cm²	Kgm/cm²									
0	2.947	-	720	·03	·63									
200	2.938	·04	720	·31	·91									
200	2.920	·11	721	·58	1.18									
00	2.900	·19	722	·86	1.46									
300	2.880	·28	722	1.14	1.74									
200	2.859	·36	723	1·41	2.01									
200	2.834	·46	724	1.69	2.29									
400	2.804	·59	725	1.96	2.56									
00	2.762	·76	726	2.23	2.83									
300	2.695	1.03	728	2.50	3.10									
000	2.573	1.53	732	2.76	3.36									
200	2.278	2.74	741	3.00	3.60									
300	1.810	4.66	756	3.07	3.67									
305	1.610	5.48	762	3.04	3.64									

FAILURE BY BULGING

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE Winger Pit - Mixture #6
LOCATION
HOLE DEPTH
TECHNICIAN [illegible] DATE 27/1/59

Machine Data:-
Machine No. T.O
Multiplication Factor -
Wt. Loading Block + Piston (gms) 21 Kgm

Description of Sample:
Native gravel crushed to 1" max.
Compacted at opt. M.C.
Felt liner used

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure (σ3) Kgm/sq. cm		0.90					
Length inches		24 1/2					
Area sq. cms.		720					
Volume ~~c.c.s.~~ cu. ft.		1.581					
Dry Unit Weight lbs/cu. ft. γd		125.2					
Gs= · Volume Soil Solids γwet		131.9					
Wt. Tare + Soil + Water at start							
Wt. Tare + Soil + Water at end		7420		Wet Soil Used		208.5	lbs.
Wt. Tare + Soil		7091					
Number and weight of Tare		833					
Wt. Soil		6258					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	329					
	Moisture content	5.25					
	Degree of saturation %	41					

Load on Pan	Dial Rdg	Strain	Area	σ1 − σ3	Load on Pan σ1	Dial Rdg.	Strain	Area	σ1	Load on Pan	Dial Rdg.	Strain	Area	σ1
Kgm	ins.	%	cm²	Kgm/cm²	Kgm/cm²									
0	2.925	–	720	.03	.93									
200	2.919	.02	721	.31	1.21									
400	2.908	.07	721	.58	1.48									
600	2.895	.12	721	.86	1.76									
800	2.881	.18	722	1.14	2.04									
1000	2.866	.24	722	1.41	2.31									
1200	2.848	.31	723	1.69	2.59									
1400	2.823	.42	723	1.96	2.86									
1600	2.790	.55	724	2.24	3.14									
1800	2.745	.74	726	2.51	3.41									
2000	2.652	1.11	729	2.77	3.67									
2200	2.500	1.74	733	3.03	3.93									
2400	2.200	2.96	742	3.26	4.16									
2600	1.710	4.96	758	3.46	4.36									
2700	1.310	6.59	771	3.53	4.43									
2800	0.740	8.92	791	3.57	4.47									
2840	0.540	9.74	798	3.58	4.48									

Failure by bulging

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TRI-AXIAL COMPRESSION

PROJECT	
SITE	
SAMPLE	WINGER PIT - MIXTURE #6
LOCATION	
HOLE	DEPTH
TECHNICIAN K.A.K.	DATE 27/1/59

Machine Data:-
Machine No. T.O.
Multiplication Factor
Wt. Loading Block + Piston (gms.) 21 Kgm.

Description of Sample:
NATIVE GRAVEL CRUSHED TO 1" MAX
COMPACTED ABOVE OPT. M.C.
FELT LINER & CIRC GAUGE USED

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure (σ_{III}) Kgm/sq.cm		0.30					
Length inches		24 5/8					
Area sq. cms.		720					
Volume ~~c.c.s.~~ cu. ft.		1.591					
Dry Unit Weight lbs/cu.ft. γ_d		137.6					
Gs= · Volume Soil Solids γ_{wet}		146.4					
Wt. Tare + Soil + Water at start							
Wt. Tare + Soil + Water at end		7096		WET SOIL USED = 233 lbs.			
Wt. Tare + Soil		6710					
Number and weight of Tare		801					
Wt. Soil		5909					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	386					
	Moisture content	6.53					
	Degree of saturation	79					

Load on Pan	Dial Rdg	Strain	Area	σ_1	Load on Pan	Dial Rdg.	Strain	Area	σ_1	Load on Pan	Dial Rdg.	Strain	Area	σ_1
LOAD	DIAL RDG	CIRC RDG	STRAIN	ΔC	AREA	$\sigma_1 - \sigma_{III}$	σ_1							
Kgm.	ins.	ins.	%	ins.	cm²	Kgm/cm²	Kgm/cm²							
0	2.968	39 29/32	–	–	720	.03	.33							
100	2.959	"	.04	–	720	.17	.47							
200	2.930	"	.15	–	720	.31	.61							
300	2.880	39 15/16	.36	1/32	722	.45	.75							
400	2.825	40	.58	3/32	724	.58	.88							
500	2.764	40 1/16	.83	5/32	727	.72	1.02							
600	2.701	40 1/8	1.08	7/32	729	.85	1.15							
700	2.630	40 3/16	1.37	9/32	731	.99	1.29							
800	2.552	40 1/4	1.69	11/32	734	1.12	1.42							
900	2.475	40 3/8	2.00	15/32	739	1.25	1.55							
1000	2.376	40 1/2	2.40	19/32	743	1.37	1.67							
1100	2.267	40 5/8	2.85	23/32	748	1.50	1.80							
200	2.145	40 13/16	3.34	29/32	756	1.62	1.92							
300	1.965	41 1/8	4.07	1 7/32	768	1.72	2.02							
1400	1.685	41 5/8	5.21	1 23/32	788	1.80	2.10							
1500	1.210	42 1/2	7.14	2 19/32	822	1.85	2.15							
1600	0.520	43 7/8	9.94	3 31/32	881	1.84	2.14							
1685	0.000	45 1/16	12.05	5 5/32	932	1.83	2.13							
						FAILURE BY BULGING								

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TRI-AXIAL COMPRESSION

PROJECT	
SITE	
SAMPLE	WINGER PIT - MIXTURE #6
LOCATION	
HOLE	DEPTH
TECHNICIAN K.U.H.	DATE 27/1/59

Machine Data:-
Machine No. T.O
Multiplication Factor —
Wt. Loading Block + Piston (gms.) 21 Kgm.

Description of Sample:
NATIVE GRAVEL CRUSHED TO 1"
MAX. COMPACTED ABOVE OPT M.C.
FELT LINER & CIRC GAUGE USED

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure (σIII) Kgm./sq.cm.		0.60					
Length	inches	24 5/8					
Area	sq. cms.	720					
Volume	~~c.c.s.~~ cu. ft.	1.591					
Dry Unit Weight	lbs/cu.ft. γd	135.7					
Gs= ·Volume Soil Solids	γwet	144.5					
Wt. Tare + Soil + Water at start							
Wt. Tare + Soil + Water at end		8515		WET SOIL USED = 230 lbs.			
Wt. Tare + Soil		8054					
Number and weight of Tare		926					
Wt. Soil		7128					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	461					
	Moisture content	6.48					
	Degree of saturation %	73					

Load on Pan	Dial Rdg	Strain	Area	σ1	Load on Pan	Dial Rdg.	Strain	Area	σ1	Load on Pan	Dial Rdg.	Strain	Area	σ1
LOAD	DIAL RDG	CIRC. RDG	STRAIN	ΔC	AREA	σ1 − σIII	σ1							
Kgm.	ins.	ins.	%	ins.	cm²	Kgm/cm²	Kgm/cm²							
0	2.942	39 7/8	–	–	720	·03	·63							
200	2.905	"	·15	–	720	·31	·91							
400	2.830	"	·46	-	720	·58	1.18							
600	2.735	"	·84	-	720	·86	1.46							
800	2.622	40	1.30	1/8	725	1.13	1.73							
1000	2.493	40 1/16	1.82	3/16	728	1.40	2.00							
1200	2.342	40 3/16	2.44	5/16	732	1.67	2.27							
1400	2.184	40 3/8	3.08	1/2	740	1.92	2.52							
1600	1.976	40 5/8	3.92	3/4	750	2.16	2.76							
1800	1.655	40 3/4	5.23	7/8	755	2.41	3.01							
2000	1.100	41 3/8	7.48	1 1/2	767	2.64	3.24							
2100	0.790	42 1/4	8.74	2 3/8	815	2.60	3.20							
2200	0.403	43	10.31	3 1/8	846	2.63	3.23							
2300	0.010	43 5/8	11.91	3 3/4	872	2.66	3.26							
2330	0.000	43 3/4	11.95	3 7/8	877	2.68	3.28							
					FAILURE BY BULGING.									

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TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE WINGER PIT - MIXTURE #6
LOCATION
HOLE DEPTH
TECHNICIAN K.A.W. DATE 27/1/59

Machine Data:-
Machine No. T.O.
Multiplication Factor —
Wt. Loading Block + Piston (gms.) 21 Kgms.

Description of Sample:
NATIVE GRAVEL CRUSHED TO 1" MAX
COMPACTED ABOVE OPT M.C.
FELT LINER & CIRC GAUGE USED

SPECIMEN DATA

Specimen Number			1	2	3	4	5	6
Lateral Pressure		(σ_{III}) Kgm/sq. cm.	0.90					
Length		inches	24 1/4					
Area		sq. cms.	720					
Volume		~~c.c.s.~~ cu. ft.	1.567					
Dry Unit Weight		lbs/cu. ft. γ_d	139.0					
Gs=		Volume Soil Solids γ_{wet}	148.0					
Wt. Tare + Soil + Water at start								
Wt. Tare + Soil + Water at end			7922		WET SOIL USED = 232			lbs.
Wt. Tare + Soil			7489					
Number and weight of Tare			782					
Wt. Soil			6707					
Before Test	Weight of water							
	Moisture content							
	Degree of saturation							
After Test	Weight of water		433					
	Moisture content		6.46					
	Degree of saturation	%	83					

Load on Pan	Dial Rdg	Strain	Area	σ_1	Load on Pan	Dial Rdg.	Strain	Area	σ_1	Load on Pan	Dial Rdg.	Strain	Area	σ_1
LOAD	DIAL RDG	CIRC RDG	STRAIN	ΔC	AREA	$\sigma_1 - \sigma_{III}$	σ_1							
Kgm	ins.	ins.	%	ins.	cm²	Kgm/cm²	Kgm/cm²							
0	2.970	40 3/16	-	-	720	.03	.93							
200	2.873	"	.40	-	720	.31	1.21							
400	2.690	40 1/4	1.16	1/16	723	.58	1.48							
600	2.500	40 3/8	1.94	3/16	728	.85	1.75							
800	2.312	40 1/2	2.71	5/16	735	1.12	2.02							
1000	2.112	40 11/16	3.54	1/2	742	1.38	2.28							
1200	1.900	40 7/8	4.41	11/16	750	1.63	2.53							
1400	1.675	41 3/16	5.34	1	759	1.87	2.77							
1600	1.396	41 9/16	6.49	1 3/8	774	2.09	2.99							
1800	1.060	42	7.88	1 13/16	792	2.30	3.20							
2000	0.695	42 1/2	9.39	2 5/16	812	2.49	3.39							
2200	0.282	43 1/4	11.08	3 1/16	843	2.63	3.53							
2380	0.040	43 5/8	12.08	3 7/16	859	2.80	3.70							
2420	0.000	43 15/16	12.25	3 3/4	872	2.80	3.70							
					FAILURE	BY	BULGING							

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SIEVE ANALYSIS

PROJECT
SITE
SAMPLE Winger Mixture #1 After
LOCATION Triaxial Tests.
HOLE DEPTH
TECHNICIAN [illegible] DATE 9/2/59

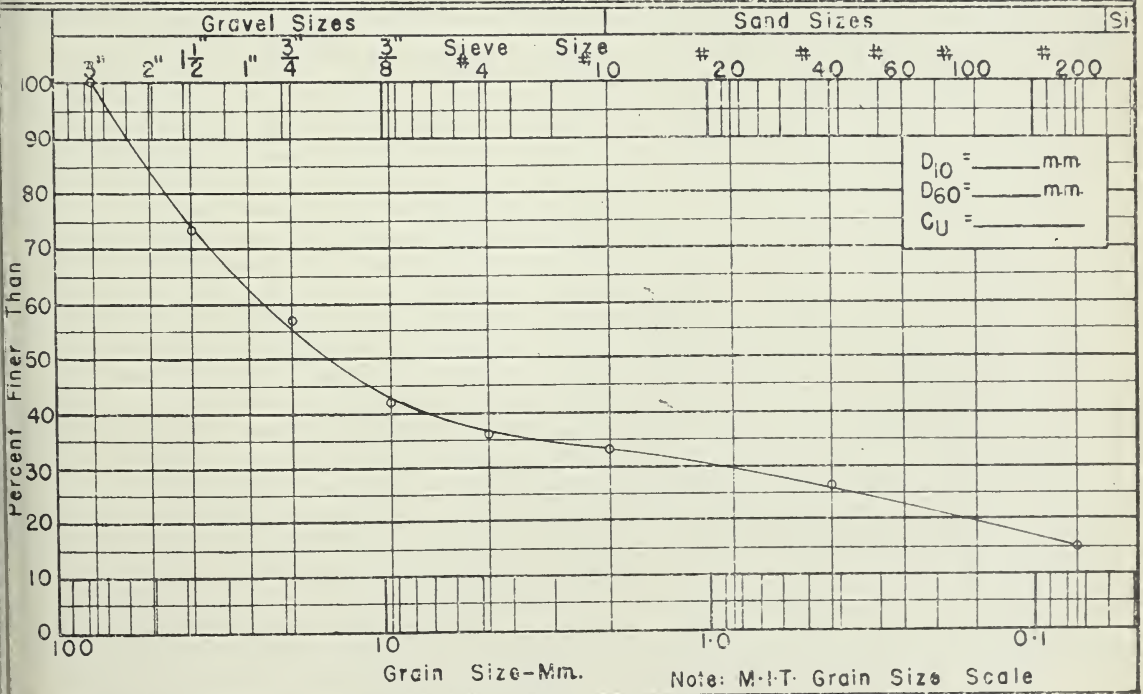
Total Dry Weight of Sample 18,476	Sieve No.	Size of Opening Inches	Size of Opening Mm.	Weight Retained gms.	Total Wt. Finer Than gms.	Percent Finer Than	% Finer Than Basis Orig. Sample
Initial Dry Weight Retained No. 4							
Tare No.		3"		-	18 476		100
Wt. Dry + Tare		1½"		4903	13 573		73
Tare		3/4	19·10	3030	10 543		57
Wt. Dry		3/8	9·52	2653	7890		42
	4	·185	4·76	1115	6775		36.1
Passing	4						
Initial Dry Weight							
Passing No. 4	10	·079	2·000	489	6286		33.4
Tare No.	20	·0331	·840				
Wt. Dry + Tare	40	·0165	·420	1329	4957		26.2
Tare	60	·0097	·250				
Wt. Dry	100	·0059	·149				
	200	·0029	·074	2187	2770		15.0
Passing	200						

Description of Sample

Time of Sieving

Method of Preparation

Remarks



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SIEVE ANALYSIS

PROJECT
SITE
SAMPLE WINGER MIXTURE #2 AFTER
LOCATION TRIAXIAL TESTS
HOLE DEPTH
TECHNICIAN K.A.H. DATE 10/2/59

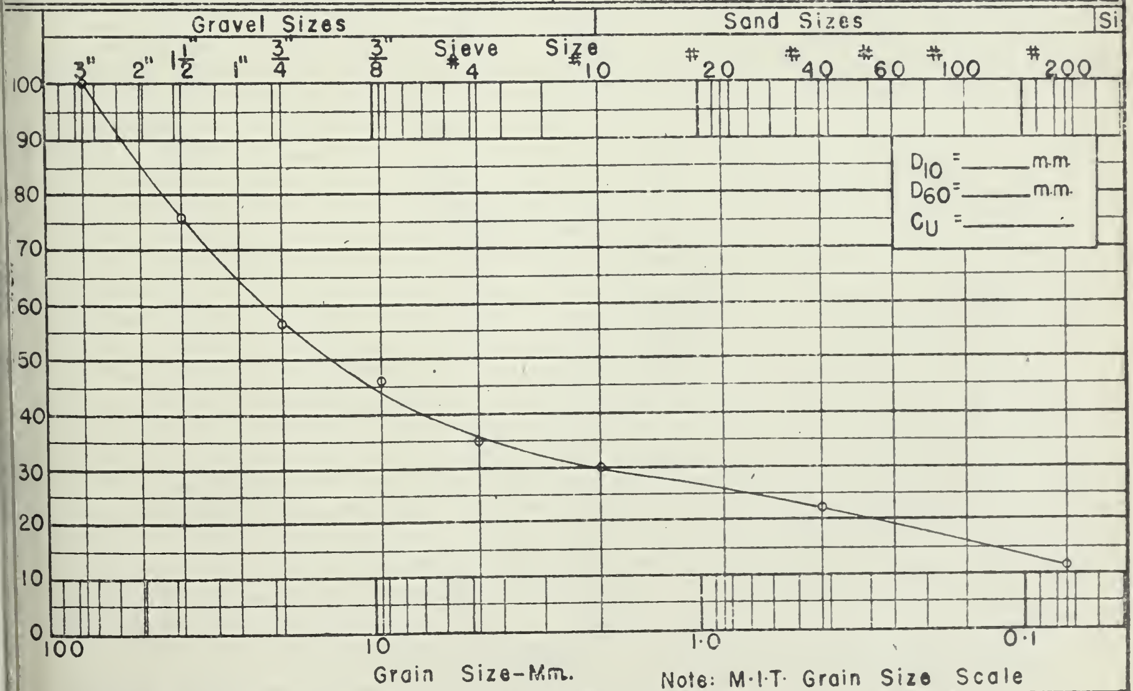
Total Dry Weight of Sample 23,370	Sieve No.	Size of Opening Inches	Mm.	Weight Retained gms.	Total Wt. Finer Than gms.	Percent Finer Than	% Finer Than E.C.S.'s Orig. Sample
Initial Dry Weight Retained No. 4							
Tare No.		3"		–	23,370		100
Wt. Dry + Tare		1½"		5,642	17,728		76
Tare		3/4	19·10	4,379	13,349		57
Wt. Dry		3/8	9·52	2,598	10,751		46
	4	·185	4·76	2,599	8,152		34.9
Passing	4						
Initial Dry Weight Passing No. 4							
	10	·079	2·000	2,160	6992		29.9
Tare No.	20	·0331	·840				
Wt. Dry + Tare	40	·0165	·420	1,876	5116		21.9
Tare	60	·0097	·250				
Wt. Dry	100	·0059	·149				
	200	·0029	·074	2,454	2662		11.4
Passing	200						

Description of Sample

Time of Sieving

Method of Preparation

Remarks



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SIEVE ANALYSIS

PROJECT
SITE
SAMPLE Winger Mixture #3 After
LOCATION Triaxial Tests
HOLE DEPTH
TECHNICIAN K.a.W. DATE 11/2/59

Total Dry Weight of Sample 27,150	Sieve No.	Size of Opening Inches	Size of Opening Mm.	Weight Retained gms.	Total Wt. Finer Than gms.	Percent Finer Than	% Finer Than Basis Orig. Sample
Initial Dry Weight Retained No. 4							
Tare No.		3"			27158		100
Wt. Dry + Tare		1½"		6330	20828		77
Tare		¾	19·10	5037	15791		58
Wt. Dry		⅜	9·52	4103	11688		43
	4	·185	4·76	2734	8954		33
Passing	4						

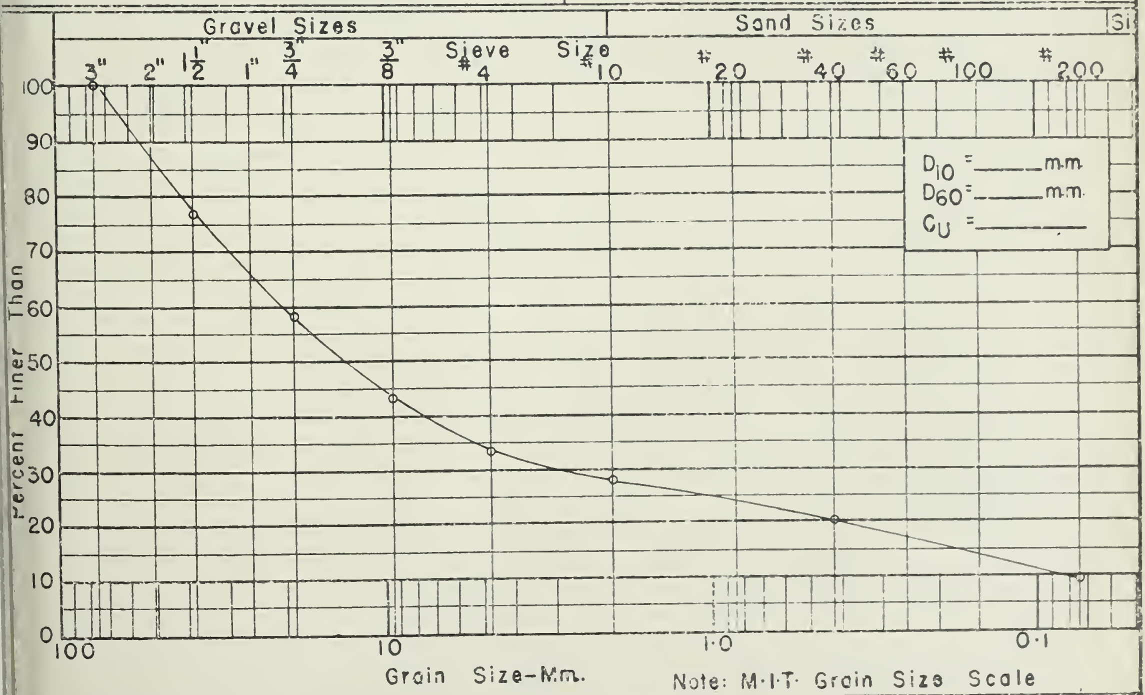
Initial Dry Weight							
Passing No. 4	10	·079	2·000	1353	7601		28
Tare No.	20	·0331	·840				
Wt. Dry + Tare	40	·0165	·420	2155	5446		20
Tare	60	·0097	·250				
Wt. Dry	100	·0059	·149				
	200	·0029	·074	2954	2492		9.2
Passing	200						

Description of Sample

Time of Sieving

Method of Preparation

Remarks



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SIEVE ANALYSIS

PROJECT
SITE
SAMPLE Winger Mixture #4 After
LOCATION Triaxial Tests.
HOLE DEPTH
TECHNICIAN [illegible] DATE 12/2/59

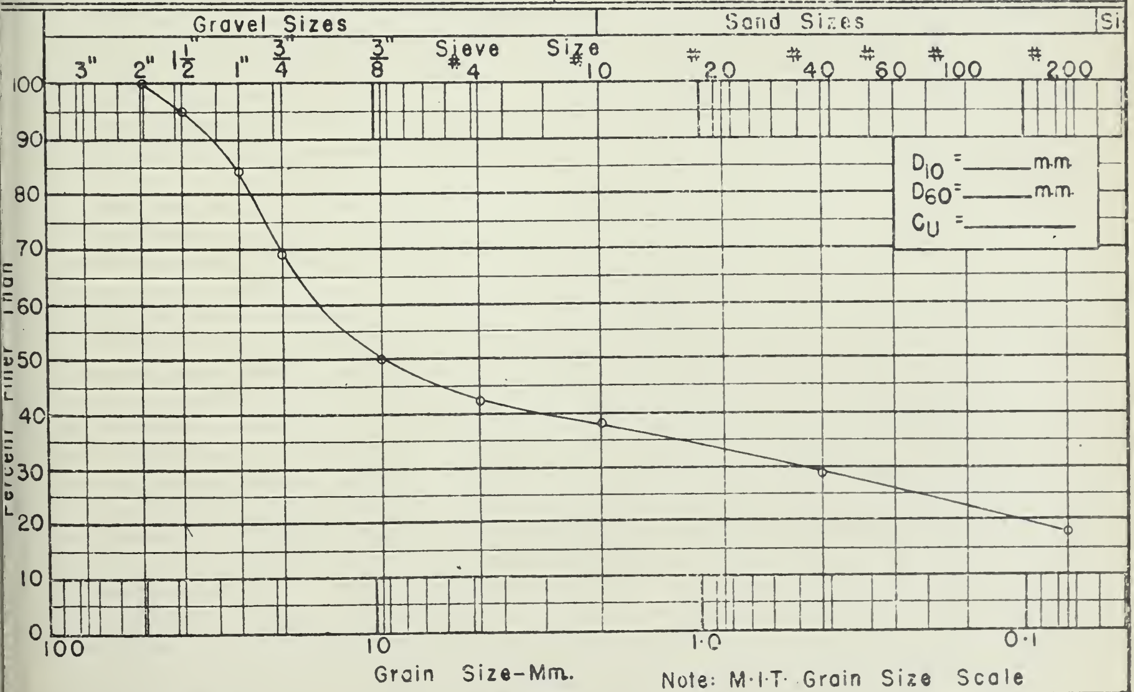
Total Dry Weight of Sample 19,937	Sieve No.	Size of Opening Inches	Size of Opening Mm.	Weight Retained gms.	Total Wt. Finer Than gms.	Percent Finer Than	% Finer Than Basis Orig. Sample
Initial Dry Weight		3		–			
Retained No. 4		2		–	19,937		100
Tare No.		1½		935	19,002		95
Wt. Dry + Tare		1		2230	16,772		84
Tare		¾	19·10	2938	13,834		69
Wt. Dry		⅜	9·52	3813	10,021		50
	4	·185	4·76	1678	8,343		42
Passing	4						
Initial Dry Weight							
Passing No. 4	10	·079	2·000	783	7560		38
Tare No.	20	·0331	·840				
Wt. Dry + Tare	40	·0165	·420	1696	5864		29
Tare	60	·0097	·250				
Wt. Dry	100	·0059	·149				
	200	·0029	·074	2286	3578		17·3
Passing	200						

Description of Sample

Time of Sieving

Method of Preparation

Remarks



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SIEVE ANALYSIS

PROJECT
SITE
SAMPLE *Winger Mixture #5 from*
LOCATION *Triaxial Tests*
HOLE DEPTH
TECHNICIAN *[illegible]* DATE *13/2/59*

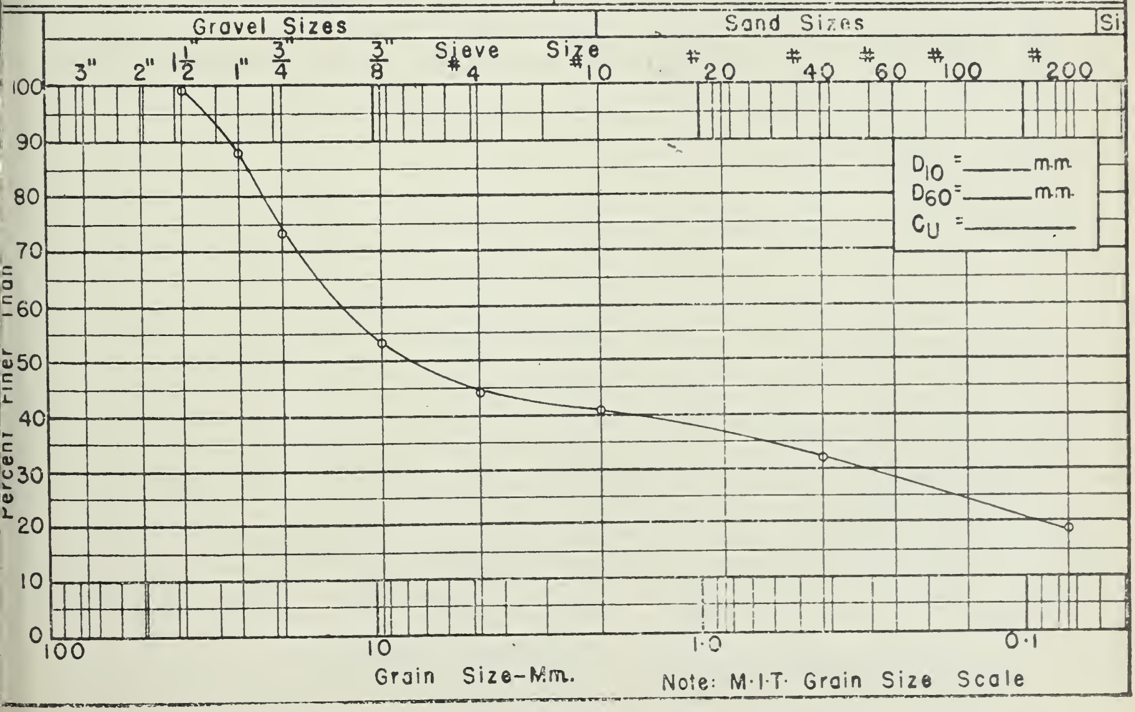
otal Dry Weight f Sample *22,665*	Sieve No.	Size of Opening Inches	Size of Opening Mm.	Weight Retained gms.	Total Wt. Finer Than gms.	Percent Finer Than	% Finer Than Basis Orig. Sample
itial Dry Weight		3					
etained No. 4		2			22 665		100
are No. ____		1½		305	22,360		99
't. Dry + Tare ____		1		2350	20,010		88
are ____		¾	19·10	3479	16,531		73
't. Dry ____		⅜	9·52	4416	12,115		53
	4	·185	4·76	2052	10,063		44
Passing	4						
itial Dry Weight							
assing No. 4	10	·079	2·000	826	9,237		41
are No. ____	20	·0331	·840				
Vt. Dry + Tare ____	40	·0165	·420	2022	7,215		32
are ____	60	·0097	·250				
Vt. Dry ____	100	·0059	·149				
	200	·0029	·074	3023	4,192		18·5
Passing	200						

Description of Sample ____

Method of Preparation ____

Remarks ____

Time of Sieving ____



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SIEVE ANALYSIS

PROJECT
SITE
SAMPLE Winger Mixture #6 After
LOCATION Triaxial Tests.
HOLE DEPTH
TECHNICIAN DATE

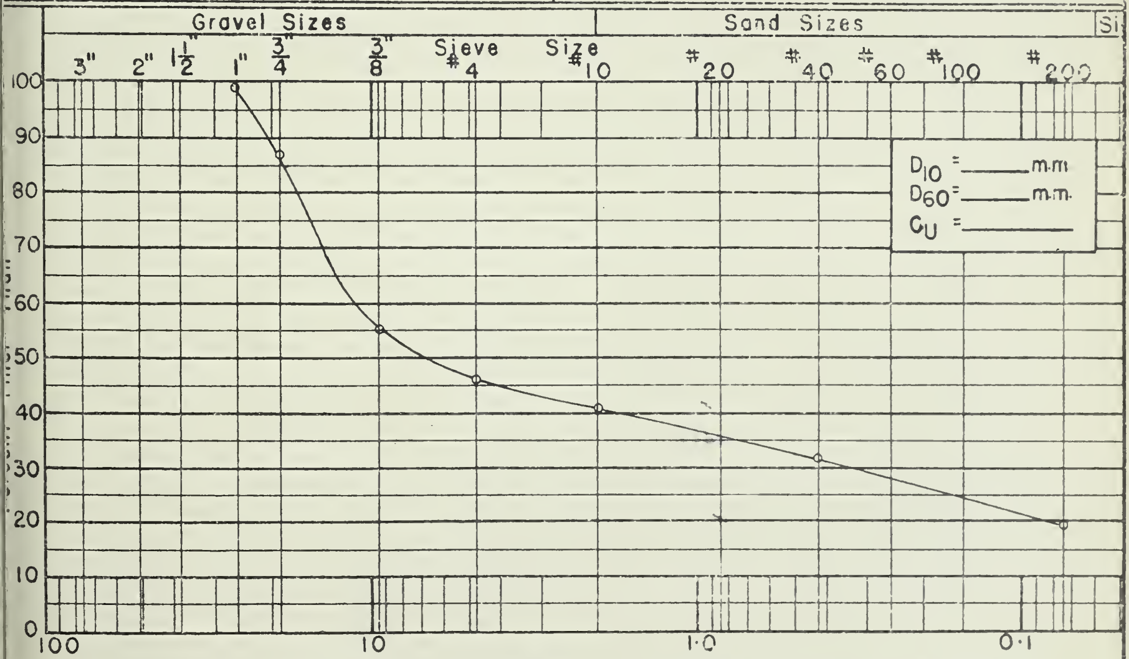
Total Dry Weight of Sample 15,785	Sieve No.	Size of Opening Inches	Size of Opening Mm.	Weight Retained gms.	Total Wt. Finer Than gms.	Percent Finer Than	% Finer Than Basis Orig. Sample
Initial Dry Weight Retained No. 4							
Tare No.		1½		–	15,785		100
Wt. Dry + Tare		1		155	15,630		99
Tare		¾	19·10	1936	13,694		87
Wt. Dry		⅜	9·52	4959	8,735		55
	4	·185	4·76	1530	7,205		46
Passing	4						
Initial Dry Weight Passing No. 4							
	10	·079	2·000	734	6471		41
Tare No.	20	·0331	·840				
Wt. Dry + Tare	40	·0165	·420	1400	5071		32
Tare	60	·0097	·250				
Wt. Dry	100	·0059	·149				
	200	·0029	·074	2052	3019		19.1
Passing	200						

Description of Sample

Time of Sieving

Method of Preparation

Remarks



Grain Size-Mm.

Note: M·I·T· Grain Size Scale

APPENDIX C

DETAILED TEST DATA FOR PART B

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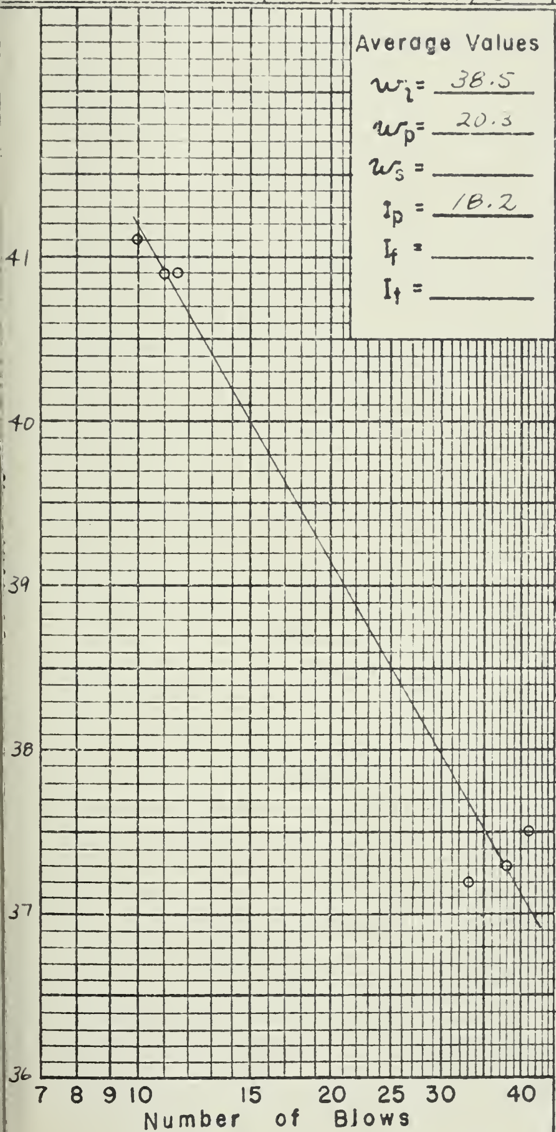
ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD - #40
LOCATION	No ADDITIVE
HOLE	DEPTH
TECHNICIAN [illegible]	DATE 28/10/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	41	38	33	11	11.5	10
Container No.	V26	V25	V24	V23	A13	A15
Wt. Sample Wet + Tare	106.99	121.47	119.11	103.57	101.77	109.11
Wt. Sample Dry + Tare	97.85	111.53	107.93	93.63	92.26	96.74
Wt. Water	9.14	9.94	11.18	9.94	9.51	12.37
Tare Container	73.50	84.86	77.88	69.34	69.01	66.64
Wt. of Dry Soil	24.35	26.67	30.05	24.29	23.25	30.10
Moisture Content w%	37.5	37.3	37.2	40.9	40.9	41.1



Average Values

w_l = 38.5

w_p = 20.3

w_s =

I_p = 18.2

I_f =

I_t =

Plastic Limit

Trial No.	1	2	3
Container No.	AH	BE	AE
Wt. Sample Wet + Tare	57.7774	61.7673	60.9505
Wt. Sample Dry + Tare	56.7938	60.5328	59.6392
Wt. Water	0.9836	1.2345	1.3113
Tare Container	52.0623	54.3916	53.0899
Wt. of Dry Soil	4.7315	6.1412	6.5493
Moisture Content %	20.8	20.1	20.0

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample:

Remarks: SAMPLE SOAKED FOR 5 HOURS BEFORE TESTING

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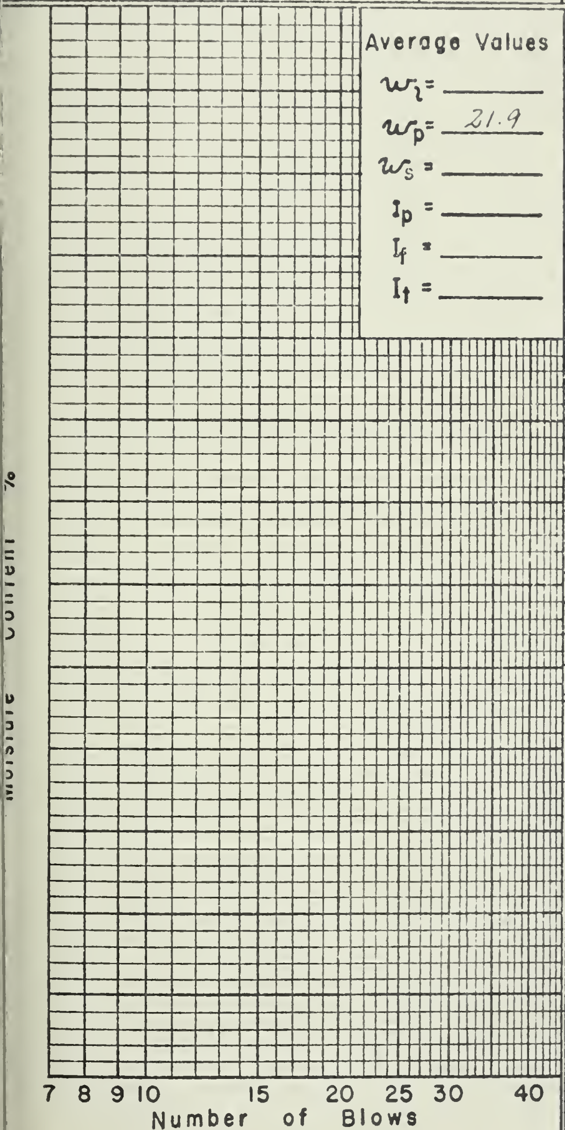
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT			
SITE			
SAMPLE	CRAWFORD -#40 & [illegible].5%		
LOCATION	NORMAL PORTLAND		
HOLE		DEPTH	
TECHNICIAN	MILLIONS	DATE	16/12/58

Liquid Limit

Trial No.						
No. of Blows						
Container No.						
Wt. Sample Wet + Tare						
Wt. Sample Dry + Tare						
Wt. Water						
Tare Container						
Wt. of Dry Soil						
Moisture Content w%						



Average Values

w_l = ______

w_p = 21.9

w_s = ______

I_p = ______

I_f = ______

I_t = ______

Plastic Limit

Trial No.	1	2	3
Container No.	BA & BG	AT	BK
Wt. Sample Wet+Tare	61.0514	61.6263	62.5749
Wt. Sample Dry+Tare	59.5220	60.2519	60.7811
Wt. Water	1.5294	1.3744	1.7938
Tare Container	52.2528	53.7176	53.2661
Wt. of Dry Soil	7.2692	6.5343	7.5150
Moisture Content %	21.0	21.0	23.8

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ______

Remarks: CURING TIME 1 HOUR.

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SOIL MECHANICS LABORATORY

ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD - #40 & 1.0%
LOCATION	NORMAL PORTLAND
HOLE	DEPTH
TECHNICIAN MILLIONS	DATE 16/12/58

Liquid Limit

Trial No.						
No. of Blows						
Container No.						
Wt. Sample Wet + Tare						
Wt. Sample Dry + Tare						
Wt. Water						
Tare Container						
Wt. of Dry Soil						
Moisture Content w%						

Average Values

w_l =

w_p = 24.7

w_s =

I_p =

I_f =

I_t =

Moisture Content %

7 8 9 10 15 20 25 30 40

Number of Blows

Plastic Limit

Trial No.	1	2	3
Container No.	BW	AH	BE
Wt. Sample Wet+Tare	63.7442	59.8052	63.2512
Wt. Sample Dry+Tare	61.9710	58.2541	61.5091
Wt. Water	1.7732	1.5511	1.7421
Tare Container	54.7360	52.0623	54.3916
Wt. of Dry Soil	7.2350	6.1918	7.1175
Moisture Content %	24.6	25.1	24.5

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample:

Remarks: CURING TIME 1 HOUR

UNIVERSITY of ALBERTA
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SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD - #40 & 1.5%
LOCATION	NORMAL PORTLAND
HOLE	DEPTH
TECHNICIAN K.A.H.	DATE 16/12/58

Liquid Limit

Trial No.						
No. of Blows						
Container No.						
Wt. Sample Wet + Tare						
Wt. Sample Dry + Tare						
Wt. Water						
Tare Container						
Wt. of Dry Soil						
Moisture Content w%						

Average Values

w_l =

w_p = 26.4

w_s =

I_p =

I_f =

I_t =

7 8 9 10 15 20 25 30 40

Number of Blows

Plastic Limit

Trial No.	1	2	3
Container No.	AD-AV	BL	AE
Wt. Sample Wet+Tare	61.4344	63.1737	61.3267
Wt. Sample Dry + Tare	59.8350	61.3889	59.5961
Wt. Water	1.5994	1.7848	1.7306
Tare Container	53.6548	54.7430	53.0899
Wt. of Dry Soil	6.1802	6.6459	6.5062
Moisture Content %	25.8	26.8	26.6

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample:

Remarks: CURING TIME 1 HOUR

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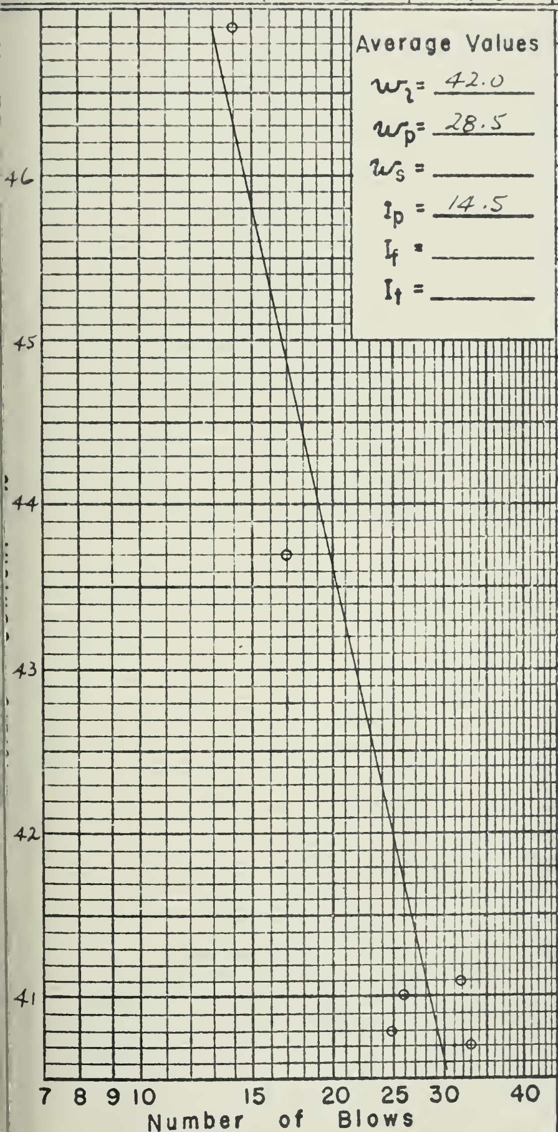
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD - #40 ē 20%
LOCATION	NORMAL PORTLAND
HOLE	DEPTH
TECHNICIAN [illegible]	DATE 31/10/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	26	25	32	33	17	14
Container No.	U23	A15	U24	V26	U25	A13
Wt. Sample Wet + Tare	100.13	92.97	109.10	101.24	114.47	96.53
Wt. Sample Dry + Tare	91.17	85.34	100.01	93.21	105.47	88.03
Wt. Water	8.96	7.63	9.09	8.03	9.00	8.50
Tare Container	69.34	66.64	77.88	73.50	84.86	69.01
Wt. of Dry Soil	21.83	18.70	22.13	19.71	20.61	19.02
Moisture Content w%	41.0	40.8	41.1	40.7	43.7	46.9



Average Values

w_l = 42.0

w_p = 28.5

w_s = ______

I_p = 14.5

I_f = ______

I_t = ______

Plastic Limit

Trial No.	1	2	3
Container No.	AE	BE	AH
Wt. Sample Wet + Tare	59.3346	60.6141	60.3824
Wt. Sample Dry + Tare	57.9624	59.2184	58.5425
Wt. Water	1.3722	1.3957	1.8399
Tare Container	53.0899	54.3916	52.0623
Wt. of Dry Soil	4.8725	4.8168	6.4802
Moisture Content %	28.2	28.9	28.4

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ______

Remarks: CURING TIME 1 HOUR

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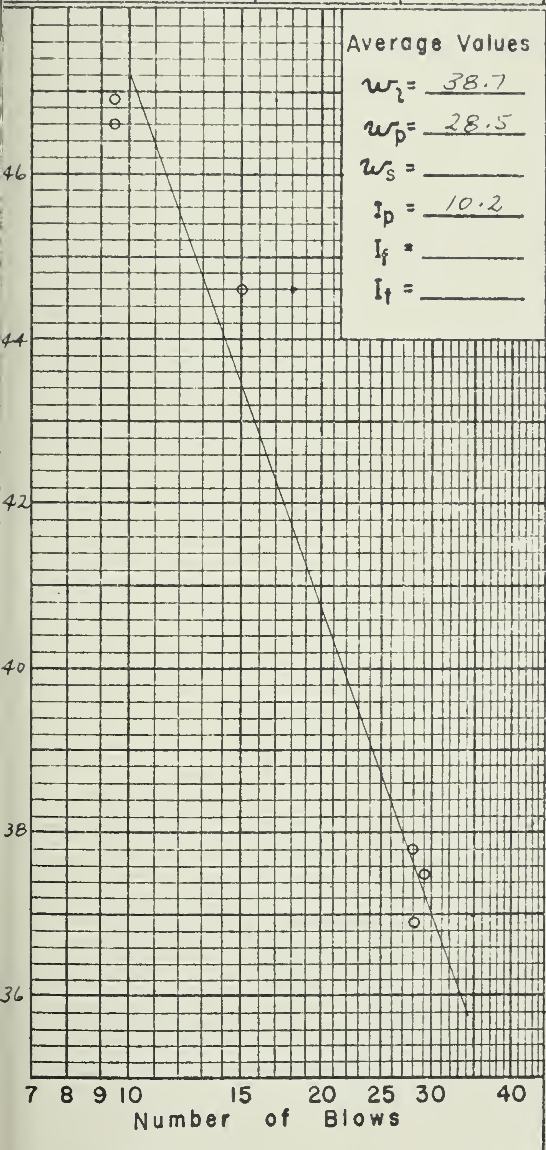
SOIL MECHANICS LABORATORY

ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD - #40 & 20%
LOCATION	NORMAL PORTLAND
HOLE	DEPTH
TECHNICIAN [illegible]	DATE 31/10/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	15	9.5	9.5	28	29	28
Container No.	V74	V72	V49	V46	V41	V42
Wt. Sample Wet + Tare	102.05	104.12	103.34	127.57	109.46	108.21
Wt. Sample Dry + Tare	92.50	93.21	93.24	115.53	99.36	97.20
Wt. Water	9.55	10.91	10.10	12.04	10.10	11.01
Tare Container	71.07	69.97	71.56	83.69	72.41	67.38
Wt. of Dry Soil	21.43	23.24	21.68	31.84	26.95	29.82
Moisture Content w%	44.6	46.9	46.6	37.8	37.5	36.9



Average Values

w_l = 38.7

w_p = 28.5

w_s = ____

I_p = 10.2

I_f = ____

I_t = ____

Plastic Limit

Trial No.	1	2	3
Container No.	AT	BK	AN
Wt. Sample Wet+Tare	59.1196	59.5682	57.4905
Wt. Sample Dry+Tare	57.9269	58.1555	56.2664
Wt. Water	1.1927	1.4127	1.2241
Tare Container	53.7176	53.2661	51.9204
Wt. of Dry Soil	4.2093	4.8894	4.3460
Moisture Content %	28.3	28.9	28.2

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

Remarks: CURING TIME 6 HOURS.

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ATTERBERG LIMITS

PROJECT
SITE
SAMPLE CRAWFORD – #40 & 2%
LOCATION NORMAL PORTLAND
HOLE DEPTH
TECHNICIAN [illegible] DATE 1/11/58

Liquid Limit

Trial No·	1	2	3	4	5	6
No. of Blows	15	17	19	22	27	27
Container No·	V42	V41	V49	V72	V74	V46
Wt· Sample Wet + Tare	109.63	109.88	108.66	106.29	110.32	121.33
Wt· Sample Dry + Tare	97.23	98.94	97.87	96.00	99.36	110.90
Wt· Water	12.40	10.94	10.79	10.29	10.96	10.43
Tare Container	67.38	72.41	71.56	69.97	71.07	83.69
Wt· of Dry Soil	29.85	26.53	26.31	26.03	28.29	27.21
Moisture Content w%	41.5	41.3	41.0	39.5	38.8	38.4

Average Values

w_l = 38.8

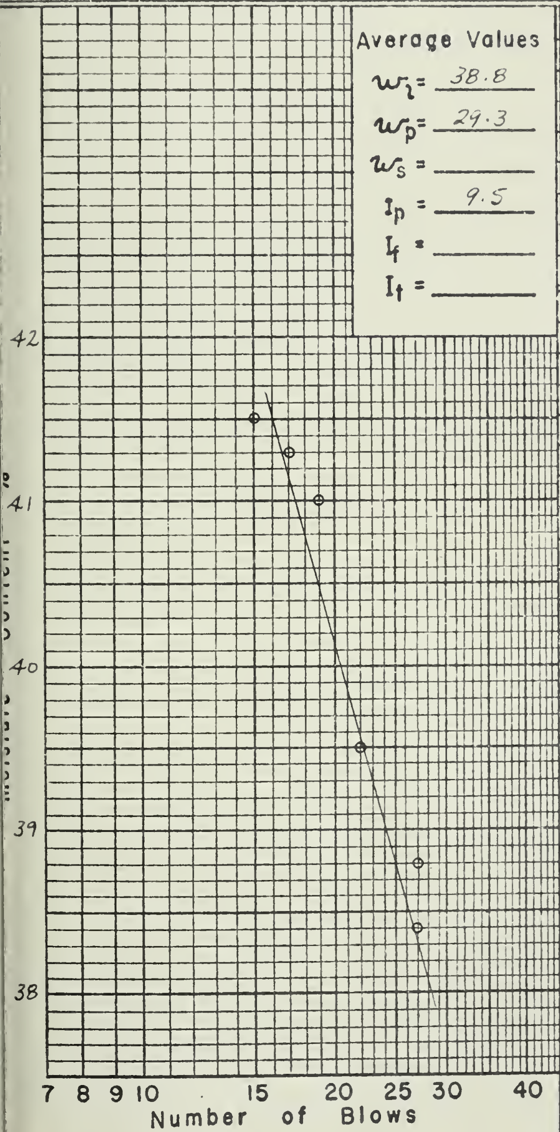
w_p = 29.3

w_s =

I_p = 9.5

I_f =

I_t =



Plastic Limit

Trial No·	1	2	3
Container No·	AN	BK	BE
Wt· Sample Wet+Tare	60.1420	58.8401	61.3918
Wt· Sample Dry+Tare	58.2903	57.5794	59.7892
Wt· Water	1.8517	1.2607	1.6026
Tare Container	51.9204	53.2661	54.3916
Wt· of Dry Soil	6.3699	4.3133	5.3976
Moisture Content %	29.1	29.2	29.7

Shrinkage Limit

Trial No·			
Container No·			
Wt· Sample Wet + Tare			
Wt· Sample Dry + Tare			
Wt· Water			
Tare Container			
Wt· of Dry Soil W_o			
Moisture Content w%			
Vol· Container V			
Vol· Dry Soil Pat V_o			
Shrinkage Vol· $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample:

Remarks: CURING TIME 26 HOURS

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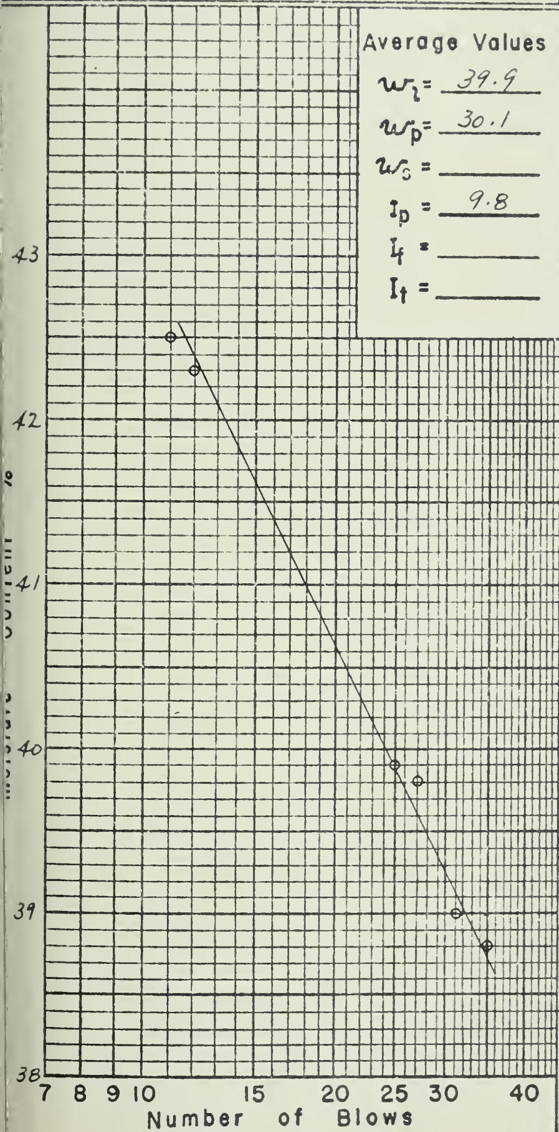
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD – #40 c̄ 2.0%
LOCATION	NORMAL PORTLAND
HOLE	DEPTH
TECHNICIAN [illegible]	DATE 7/11/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	27	25	11	12	31	35
Container No.	V24	V26	V25	V42	V41	V72
Wt. Sample Wet + Tare	116.17	109.85	118.14	105.62	109.37	104.66
Wt. Sample Dry + Tare	105.26	99.49	108.22	94.25	99.00	94.96
Wt. Water	10.91	10.36	9.92	11.37	10.37	9.70
Tare Container	77.88	73.50	84.86	67.38	72.41	69.97
Wt. of Dry Soil	27.38	25.99	23.36	26.87	26.59	24.99
Moisture Content w%	39.8	39.9	42.5	42.3	39.0	38.8



Average Values

w_l = 39.9

w_p = 30.1

w_s =

I_p = 9.8

I_f =

I_t =

Plastic Limit

Trial No.	1	2	
Container No.	AT	BE	
Wt. Sample Wet+Tare	63.9010	61.7211	
Wt. Sample Dry + Tare	61.5295	60.0363	
Wt. Water	2.3715	1.6848	
Tare Container	53.7176	54.3916	
Wt. of Dry Soil	7.8119	5.6447	
Moisture Content %	30.4	29.8	

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ______

Remarks: CURING TIME 168 HOURS.

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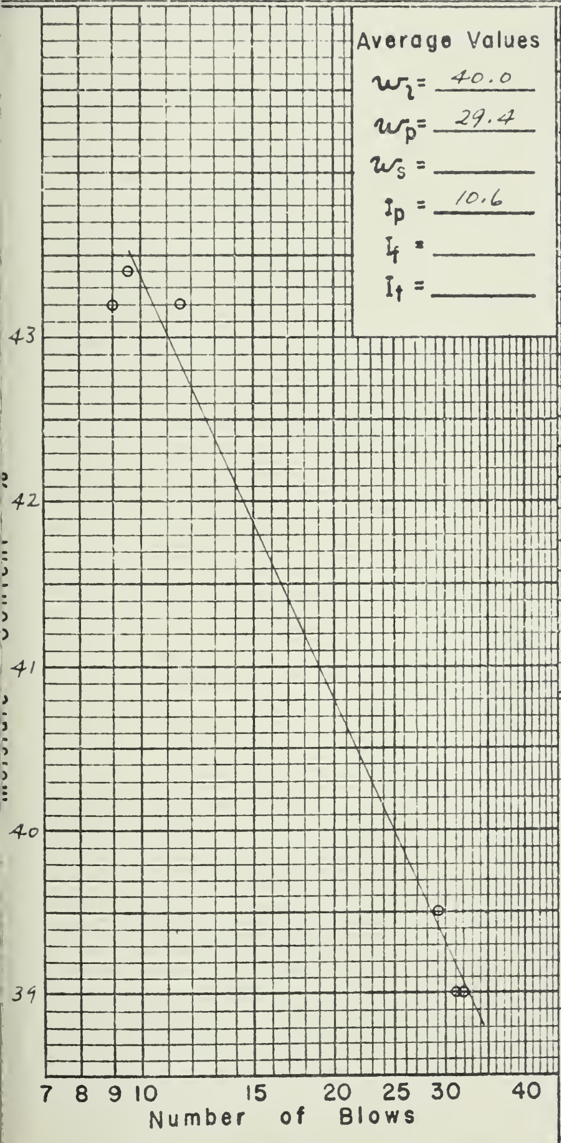
SOIL MECHANICS LABORATORY

ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD – #40 & 2%
LOCATION	NORMAL PORTLAND
HOLE	DEPTH
TECHNICIAN [illegible]	DATE 28/11/58

Liquid Limit

rial No.	1	2	3	4	5	6
o. of Blows	29	31	32	9.5	9	11.5
ontainer No.	V41	V46	V26	V23	V24	V49
't· Sample Wet + Tare	110.33	114.74	109.85	104.21	114.09	106.55
't· Sample Dry + Tare	99.60	104.63	99.66	93.65	103.16	96.00
't· Water	10.73	10.11	10.19	10.56	10.93	10.55
are Container	72.41	83.69	73.50	69.34	77.88	71.56
't· of Dry Soil	27.19	25.94	26.16	24.31	25.28	24.44
oisture Content w%	39.5	39.0	39.0	43.4	43.2	43.2



Average Values

w_l = 40.0

w_p = 29.4

w_s =

I_p = 10.6

I_f =

I_t =

Plastic Limit

Trial No.	1	2	3
Container No.	BK	BE	AN
Wt· Sample Wet + Tare	58.8657	65.2346	63.7941
Wt· Sample Dry + Tare	57.6474	62.7678	61.0466
Wt· Water	1.2183	2.4668	2.7475
Tare Container	53.2661	54.3916	51.9204
Wt· of Dry Soil	4.3813	8.3762	9.1262
Moisture Content %	27.8	29.4	30.1

Shrinkage Limit

Trial No.			
Container No.			
Wt· Sample Wet + Tare			
Wt· Sample Dry + Tare			
Wt· Water			
Tare Container			
Wt· of Dry Soil W_o			
Moisture Content w%			
Vol· Container V			
Vol· Dry Soil Pat V_o			
Shrinkage Vol· $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ______

Remarks: CURING TIME 680 HOURS.

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SOIL MECHANICS LABORATORY

ATTERBERG LIMITS

PROJECT			
SITE			
SAMPLE	CRANFORD - #40 & 2.5%		
LOCATION	NORMAL PORTLAND		
HOLE		DEPTH	
TECHNICIAN	B.A.M.	DATE	17/12/58

Liquid Limit

ial No·						
). of Blows						
ontainer No·						
t· Sample Wet + Tare						
t· Sample Dry + Tare						
t· Water						
are Container						
t· of Dry Soil						
oisture Content w%						

7 8 9 10 15 20 25 30 40
Number of Blows

Average Values

w_l =
w_p = 27.6
w_s =
I_p =
I_f =
I_t =

Plastic Limit

Trial No·	1	2	3
Container No·	BA-BG	BK	BE
Wt· Sample Wet+Tare	61.5440	63.1694	63.7453
Wt· Sample Dry + Tare	59.5262	61.0503	61.7067
Wt· Water	2.0168	2.1191	2.0386
Tare Container	52.2528	53.2661	54.3916
Wt· of Dry Soil	7.2734	7.7842	7.3151
Moisture Content %	27.7	27.2	27.8

Shrinkage Limit

Trial No·			
Container No·			
Wt· Sample Wet + Tare			
Wt· Sample Dry + Tare			
Wt· Water			
Tare Container			
Wt· of Dry Soil W_o			
Moisture Content w%			
Vol· Container V			
Vol· Dry Soil Pat V_o			
Shrinkage Vol· $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____________

Remarks: CURING TIME 1 HOUR

UNIVERSITY of ALBERTA
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SOIL MECHANICS LABORATORY

ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD - #40 & 50%
LOCATION	NORMAL PORTLAND
HOLE	/ DEPTH
TECHNICIAN [illegible]	DATE 3/11/58

Liquid Limit

rial No.	1	2	3	4	5	6
o. of Blows	38	35	36	7	9	9
ontainer No.	V23	A13	V26	A15	V25	V24
't. Sample Wet + Tare	117.08	103.16	109.35	100.67	117.50	114.62
t. Sample Dry + Tare	105.11	94.66	100.42	90.70	107.98	103.92
't. Water	11.97	8.50	8.93	9.97	9.52	10.70
are Container	69.34	69.01	73.50	66.64	84.86	77.88
t. of Dry Soil	35.77	25.65	26.92	24.06	23.12	26.04
oisture Content w%	33.5	33.1	33.2	41.5	41.2	41.0

Average Values

w_l = 35.4

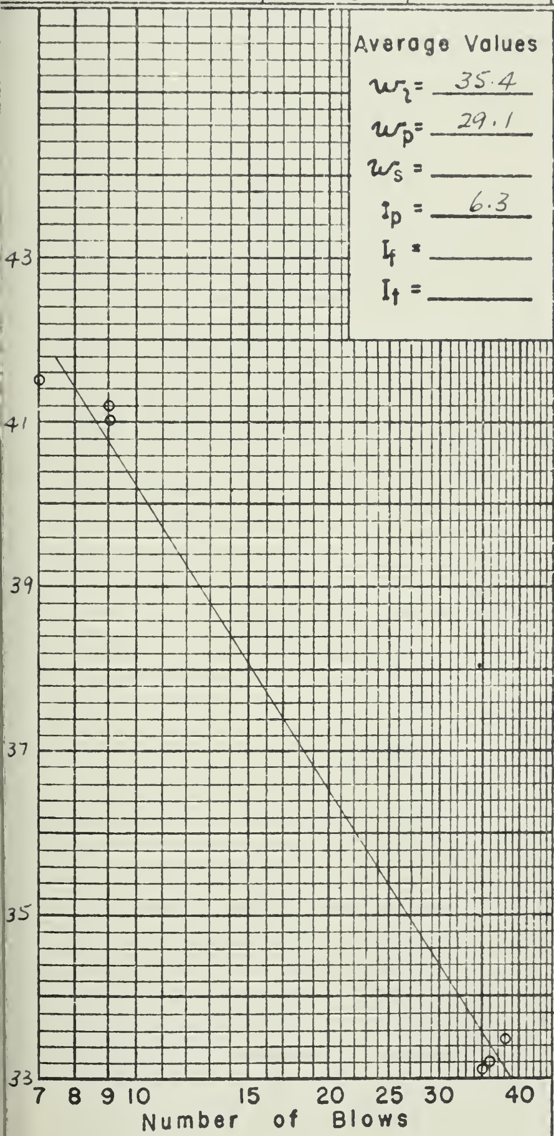
w_p = 29.1

w_s =

I_p = 6.3

I_f =

I_t =



Plastic Limit

Trial No.	1	2	3
Container No.	AT	AH	AE
Wt. Sample Wet+Tare	62.8392	60.0827	60.5952
Wt. Sample Dry+Tare	60.8337	58.2796	58.8633
Wt. Water	2.0055	1.8031	1.7319
Tare Container	53.7176	52.0623	53.0899
Wt. of Dry Soil	7.1161	6.2173	5.7734
Moisture Content %	28.2	29.0	30.0

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ______

Remarks: CURING TIME 1 HOUR

UNIVERSITY of ALBERTA
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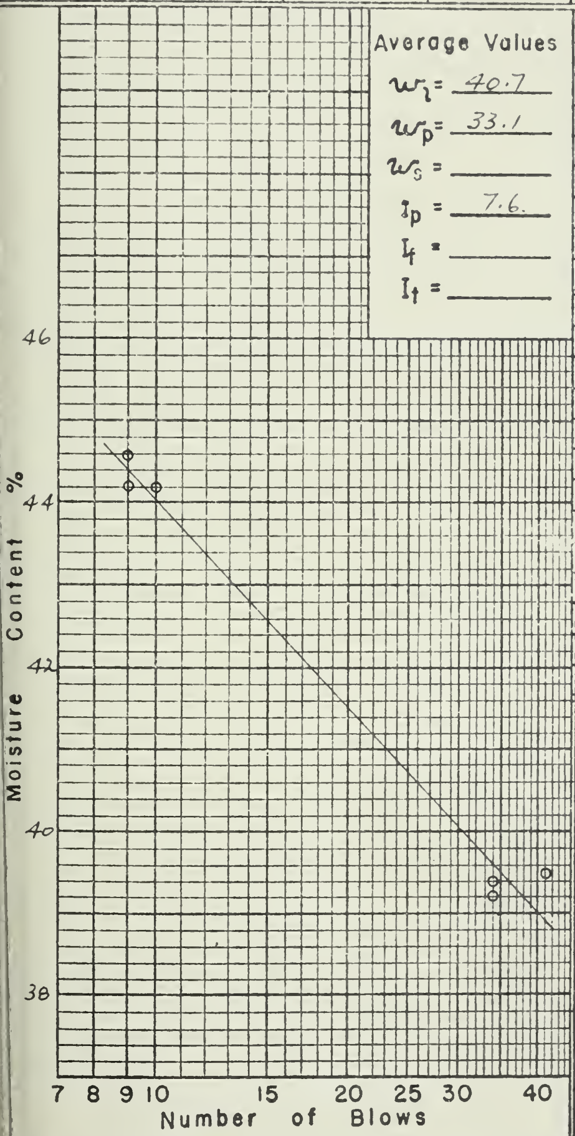
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD - #40 & 50%
LOCATION	NORMAL PORTLAND
HOLE	1 — DEPTH
TECHNICIAN	K. [illegible] — DATE 3/11/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	9	10	9	34	41	34
Container No.	V46	V74	V42	V41	V49	V72
Wt. Sample Wet + Tare	125.56	116.38	104.88	115.05	109.43	103.95
Wt. Sample Dry + Tare	112.65	102.49	93.39	102.99	98.72	94.39
Wt. Water	12.91	13.89	11.49	12.06	10.71	9.56
Tare Container	83.69	71.07	67.38	72.41	71.56	69.97
Wt. of Dry Soil	28.96	31.42	26.01	30.58	27.16	24.42
Moisture Content w%	44.6	44.2	44.2	39.4	39.5	39.2



Average Values

w_l = 40.7

w_p = 33.1

w_s = ______

I_p = 7.6

I_f = ______

I_t = ______

Plastic Limit

Trial No.	1	2	3
Container No.	BE	BK	AN
Wt. Sample Wet + Tare	61.4784	61.8221	60.0098
Wt. Sample Dry + Tare	59.7814	59.6855	57.9381
Wt. Water	1.6970	2.1366	2.0717
Tare Container	54.3916	53.2661	51.9204
Wt. of Dry Soil	5.3898	6.4194	6.0177
Moisture Content %	31.5	33.3	34.4

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ______

Remarks: CURING TIME 6 HOURS.

UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD - #40 & 5.0 %
LOCATION	NORMAL PORTLAND
HOLE	DEPTH
TECHNICIAN [illegible]	DATE 4/11/58

Liquid Limit

rial No.	1	2	3	4	5	6
lo. of Blows	41	39	38	7	9	26
ontainer No.	V46	V74	V49	V41	V24	V42
Vt. Sample Wet + Tare	130.83	109.15	109.41	110.26	113.62	105.41
Vt. Sample Dry + Tare	117.38	98.69	99.03	98.39	102.43	94.49
Vt. Water	13.45	10.46	10.38	11.87	11.19	10.92
are Container	83.69	71.07	71.56	72.41	77.88	67.38
Vt. of Dry Soil	33.69	27.62	27.47	25.98	24.55	27.11
oisture Content w%	39.9	37.9	37.8	45.7	45.6	40.3

Average Values

w_l = 40.2

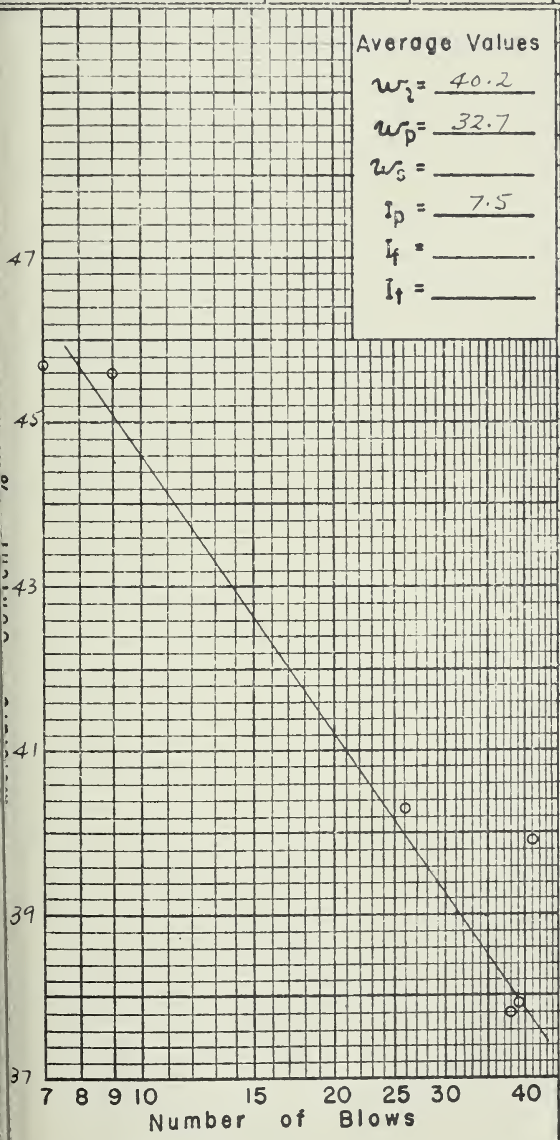
w_p = 32.7

w_s = ______

I_p = 7.5

I_f = ______

I_t = ______



Plastic Limit

Trial No.	1	2	3
Container No.	AN	BK	AE
Wt. Sample Wet + Tare	58.7157	61.3276	60.9572
Wt. Sample Dry + Tare	57.0541	59.3602	58.9811
Wt. Water	1.6616	1.9674	1.9761
Tare Container	51.9204	53.2661	53.0899
Wt. of Dry Soil	5.1337	6.0941	5.8912
Moisture Content %	32.4	32.3	33.5

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ______

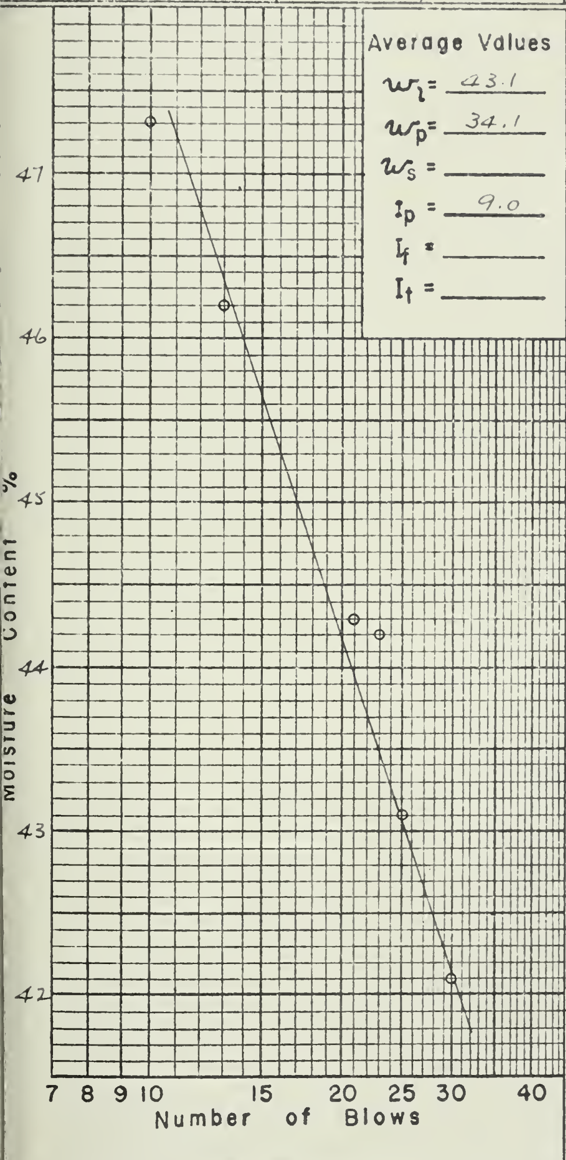
Remarks: CURING TIME 36 HOURS.

UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD - #40 5 [illegible] %
LOCATION	NORMAL PORTLAND
HOLE	DEPTH
TECHNICIAN [illegible]	DATE 11/11/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	21	23	13	10	25	30
Container No.	V23	V41	V25	A13	V44	V46
Wt. Sample Wet + Tare	104.90	103.79	118.12	99.00	108.16	111.87
Wt. Sample Dry + Tare	93.98	94.17	107.58	89.37	97.13	103.52
Wt. Water	10.92	9.62	10.54	9.63	11.03	8.35
Tare Container	69.34	72.41	84.86	69.01	71.56	83.69
Wt. of Dry Soil	24.64	21.76	22.72	20.36	25.57	19.83
Moisture Content w%	44.3	44.2	46.4	47.3	43.1	42.1



Average Values

w_l = 43.1

w_p = 34.1

w_s =

I_p = 9.0

I_f =

I_t =

Plastic Limit

Trial No.	1	2	3
Container No.	AH	AT	BK
Wt. Sample Wet+Tare	58.0263	61.6297	61.7384
Wt. Sample Dry+Tare	56.5132	59.6233	59.5801
Wt. Water	1.5131	2.0064	2.1583
Tare Container	52.0623	53.7176	53.2661
Wt. of Dry Soil	4.4509	5.9057	6.3140
Moisture Content %	34.0	33.9	34.2

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample:

Remarks: CURING TIME 196 HOURS.

UNIVERSITY of ALBERTA
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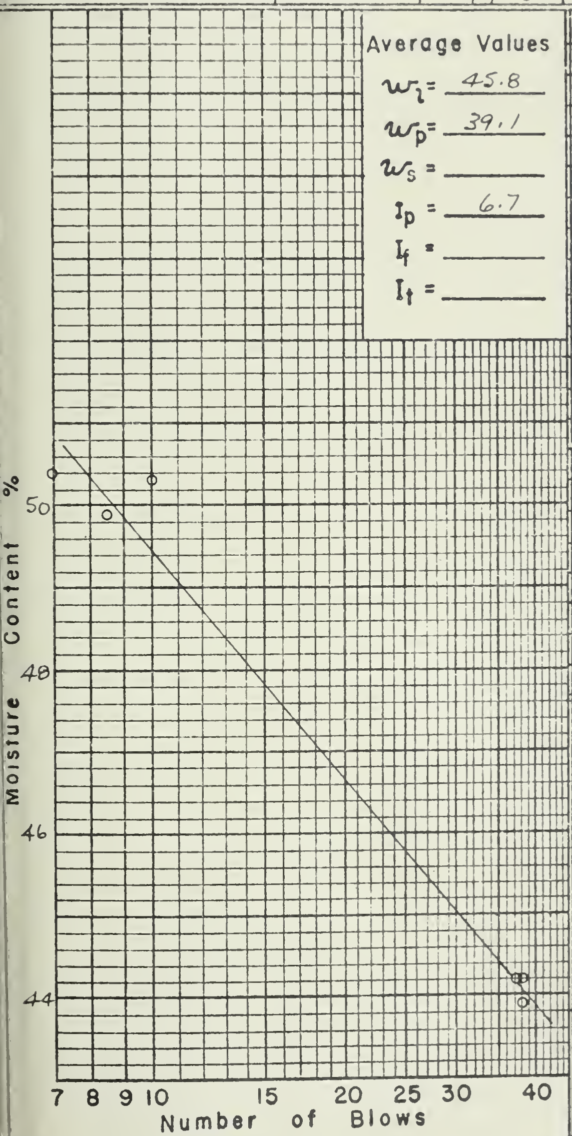
SOIL MECHANICS LABORATORY

ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD - #4 & 5%
LOCATION	NORMAL PORTLAND
HOLE	DEPTH
TECHNICIAN [illegible]	DATE 11/2/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	37	38	38	7	10	8
Container No.	V25	V72	A15	V74	A13	V42
Wt. Sample Wet + Tare	126.81	104.23	104.40	104.62	107.76	105.81
Wt. Sample Dry + Tare	113.96	93.73	92.88	93.38	94.80	93.02
Wt. Water	12.85	10.50	11.52	11.24	12.96	12.79
Tare Container	84.86	69.97	66.64	71.07	69.01	67.38
Wt. of Dry Soil	29.10	23.76	26.24	22.31	25.79	25.64
Moisture Content w%	44.2	44.2	43.9	50.4	50.3	49.9



Average Values

w_l = 45.8

w_p = 39.1

w_s = ______

I_p = 6.7

I_f = ______

I_t = ______

Plastic Limit

Trial No.	1	2	3
Container No.	AH	AT	AE
Wt. Sample Wet + Tare	64.6435	65.3504	63.1893
Wt. Sample Dry + Tare	61.1292	62.0694	60.3429
Wt. Water	3.5143	3.2810	2.8464
Tare Container	52.0623	53.7176	53.0899
Wt. of Dry Soil	9.0669	8.3518	7.2530
Moisture Content %	38.8	39.3	39.2

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ______

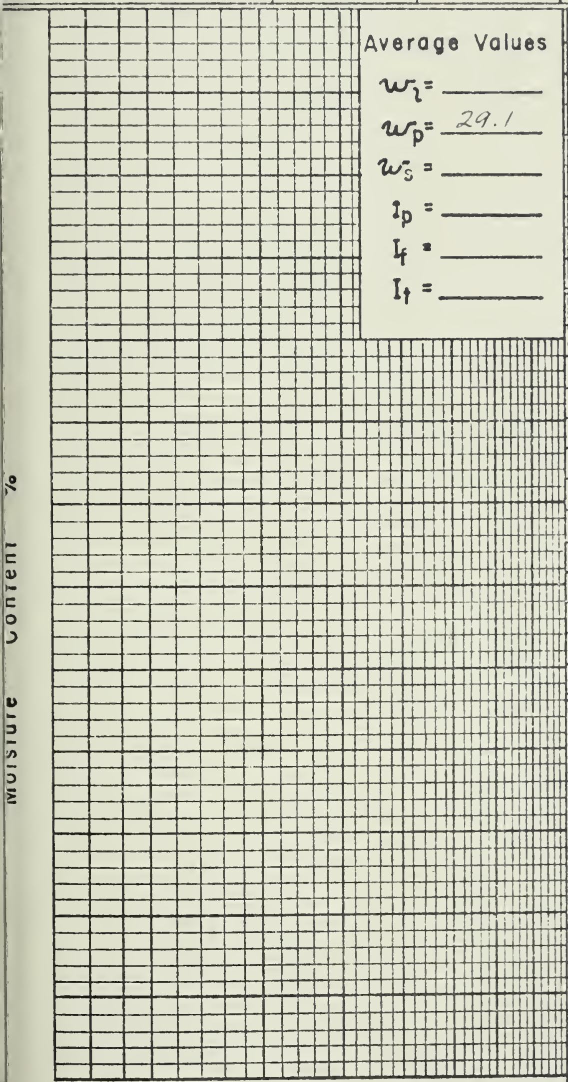
Remarks: CURING TIME 678 HOURS

UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD - #40 & 6.5%
LOCATION	NORMAL PORTLAND
HOLE /	DEPTH
TECHNICIAN [illegible]	DATE 7/12/58

Liquid Limit

Trial No.						
No. of Blows						
Container No.						
Wt. Sample Wet + Tare						
Wt. Sample Dry + Tare						
Wt. Water						
Tare Container						
Wt. of Dry Soil						
Moisture Content w%						



Average Values

w_l = ______

w_p = 29.1

w_s = ______

I_p = ______

I_f = ______

I_t = ______

Plastic Limit

Trial No.	1	2	3
Container No.	BW	AE	BL
Wt. Sample Wet+Tare	65.9070	61.6643	63.8387
Wt. Sample Dry+Tare	63.3590	59.7290	61.8300
Wt. Water	2.5480	1.9353	2.0087
Tare Container	54.7360	53.0899	54.7430
Wt. of Dry Soil	8.6230	6.6391	7.0870
Moisture Content %	29.6	29.2	28.4

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ______

Remarks: CURING TIME 1 HOUR

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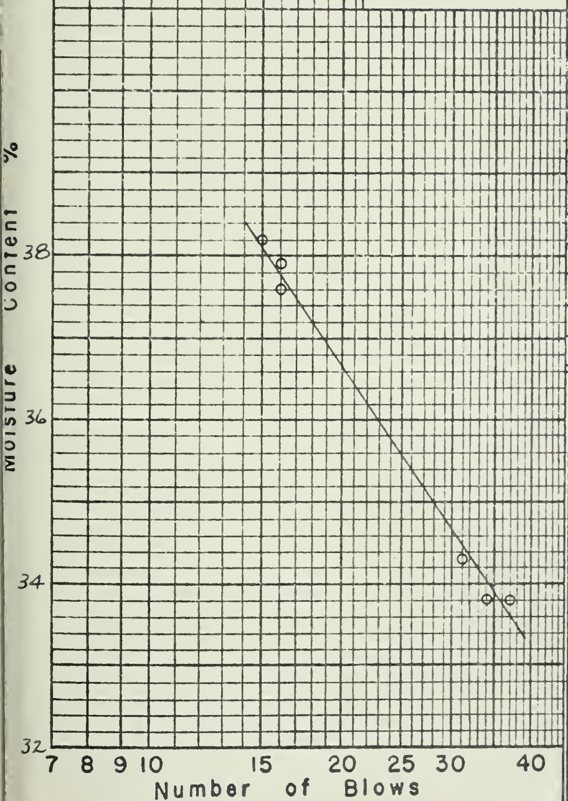
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD - #20 & 8.0%
LOCATION	NORMAL PORTLAND
HOLE	DEPTH
TECHNICIAN [illegible]	DATE 5/11/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	31	34	37	15	16	16
Container No.	V26	V23	V72	A13	V25	A15
Wt. Sample Wet + Tare	116.07	108.70	112.97	112.19	123.72	107.84
Wt. Sample Dry + Tare	105.19	98.76	102.11	100.25	113.05	96.58
Wt. Water	10.88	9.94	10.86	11.94	10.67	11.26
Tare Container	73.50	69.34	69.97	69.01	84.86	66.64
Wt. of Dry Soil	31.69	29.42	32.14	31.24	28.19	29.94
Moisture Content w%	34.3	33.8	33.8	38.2	37.9	37.6



Average Values

w_l = 35.6

w_p = 29.0

w_s =

I_p = 6.6

I_f =

I_t =

Plastic Limit

Trial No.	1	2	3
Container No.	AT	AH	BE
Wt. Sample Wet + Tare	62.1247	61.6946	64.0663
Wt. Sample Dry + Tare	60.2538	59.5568	61.8356
Wt. Water	1.8709	2.1378	2.2307
Tare Container	53.7176	52.0623	54.3916
Wt. of Dry Soil	6.5362	7.4945	7.4440
Moisture Content %	28.6	28.5	30.0

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample:

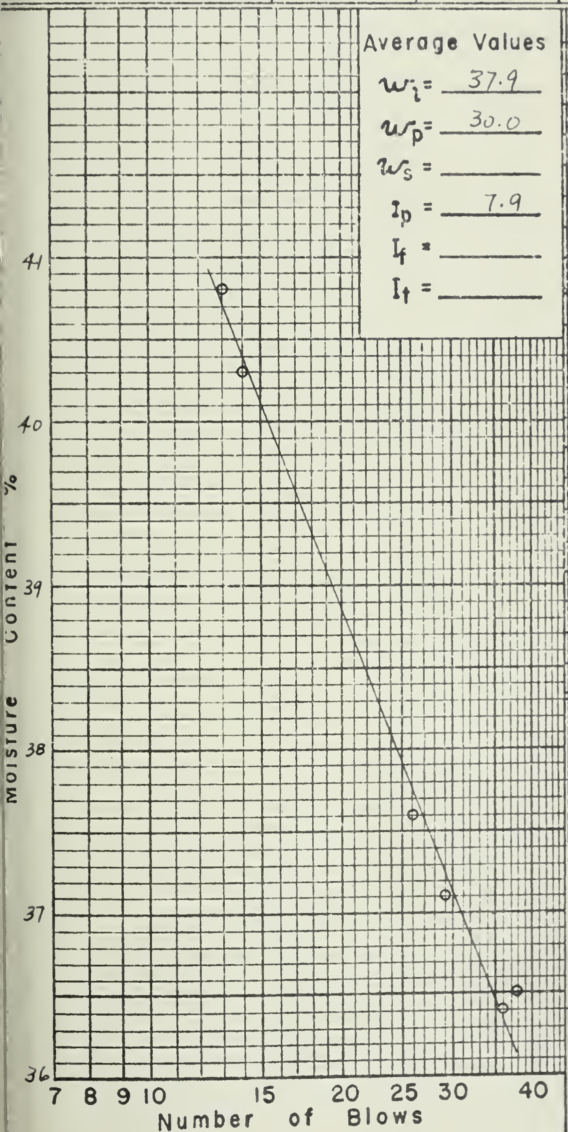
Remarks: CURING TIME 1 HOUR

UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD - #40 & 8.0%
LOCATION	NORMAL PORTLAND
HOLE	DEPTH
TECHNICIAN	DATE 5/11/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	29	36	38	13	14	26
Container No.	V42	V46	V49	V41	V24	V74
Wt. Sample Wet + Tare	105.87	118.39	105.89	104.46	112.09	106.46
Wt. Sample Dry + Tare	95.46	109.12	96.72	95.18	102.27	96.80
Wt. Water	10.41	9.27	9.17	9.28	9.82	9.66
Tare Container	67.38	83.69	71.56	72.41	77.88	71.07
Wt. of Dry Soil	28.08	25.43	25.16	22.77	24.39	25.73
Moisture Content w%	37.1	36.4	36.5	40.8	40.3	37.6



Average Values

w_l = 37.9

w_p = 30.0

w_s =

I_p = 7.9

I_f =

I_t =

Plastic Limit

Trial No.	1	2	3
Container No.	AE	BK	AN
Wt. Sample Wet + Tare	60.5865	62.2437	62.0141
Wt. Sample Dry + Tare	58.8617	60.1857	59.6587
Wt. Water	1.7248	2.0580	2.3554
Tare Container	53.0899	53.2661	51.9204
Wt. of Dry Soil	5.7718	6.4196	7.7383
Moisture Content %	29.9	29.8	30.4

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ______

Remarks: CURING TIME 6 HOURS

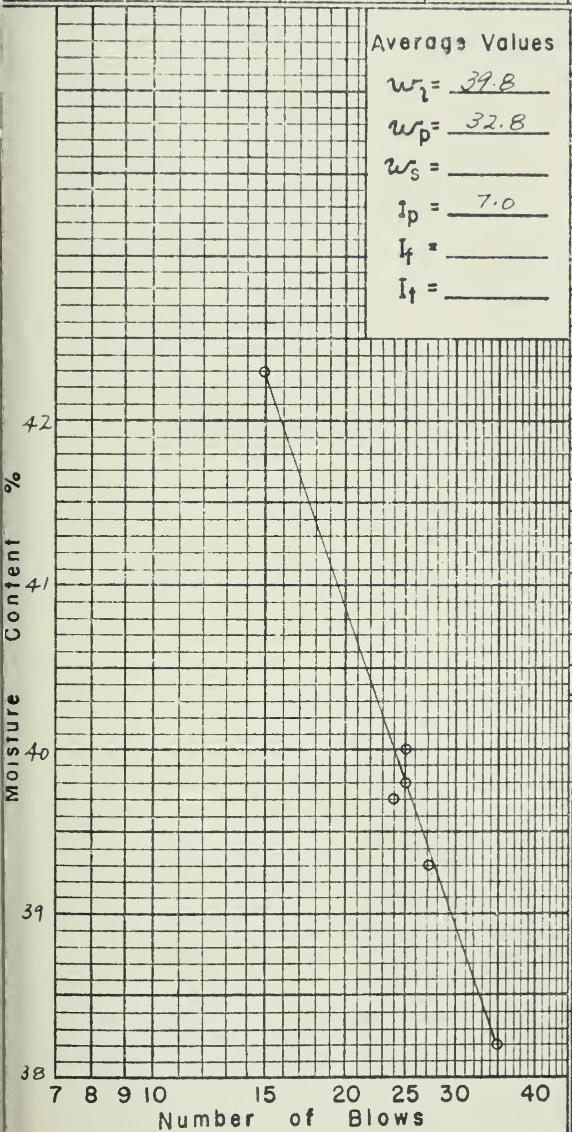
UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD – #40 & 8.0%
LOCATION	NORMAL PORTLAND
HOLE	/ DEPTH
TECHNICIAN	K.A.M. DATE 6/11/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	24	25	27	25	15	35
Container No.	A13	A15	V23	V74	V46	V49
Wt. Sample Wet + Tare	107.16	101.19	104.15	103.88	116.74	101.67
Wt. Sample Dry + Tare	96.32	91.35	94.33	94.51	106.91	93.35
Wt. Water	10.84	9.84	9.82	9.37	9.83	8.32
Tare Container	69.01	66.64	69.34	71.07	83.69	71.56
Wt. of Dry Soil	27.31	24.71	24.99	23.44	23.22	21.79
Moisture Content w%	39.7	39.8	39.3	40.0	42.3	38.2



Average Values

w_l = 39.8

w_p = 32.8

w_s = ______

I_p = 7.0

I_f = ______

I_t = ______

Plastic Limit

Trial No.	1	2	3
Container No.	BK	AN	AE
Wt. Sample Wet+Tare	60.2465	59.7074	64.1656
Wt. Sample Dry + Tare	58.5115	57.8007	61.4170
Wt. Water	1.7350	1.9067	2.7486
Tare Container	53.2661	51.9204	53.0899
Wt. of Dry Soil	5.2454	5.8803	8.3271
Moisture Content %	33.1	32.4	33.0

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ______

Remarks: CURING TIME 32.5 HOURS.

UNIVERSITY of ALBERTA
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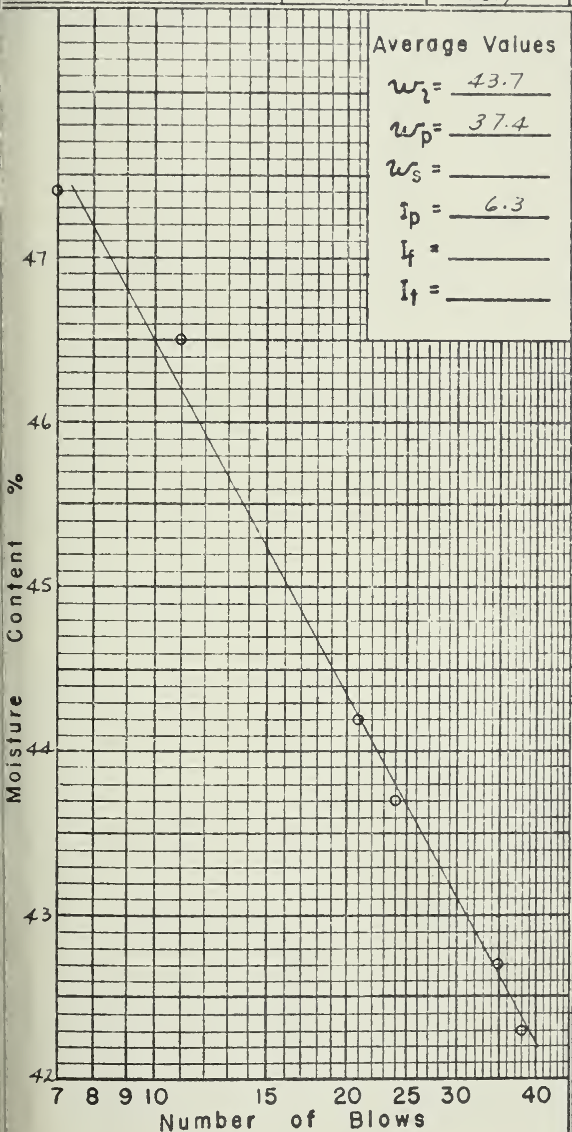
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT
SITE
SAMPLE CRAWFORD - #40 & 8.0%
LOCATION NORMAL PORTLAND
HOLE DEPTH
TECHNICIAN K.R.W. DATE 13/11/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	21	24	7	11	35	38
Container No.	V74	V72	V42	A15	V26	V24
Wt. Sample Wet + Tare	103.27	100.56	106.04	102.41	105.56	112.16
Wt. Sample Dry + Tare	93.40	91.26	93.61	91.06	95.96	101.97
Wt. Water	9.87	9.30	12.43	11.35	9.60	10.19
Tare Container	71.07	69.97	67.38	66.64	73.50	77.88
Wt. of Dry Soil	22.33	21.29	26.23	24.42	22.46	24.09
Moisture Content w%	44.2	43.7	47.4	46.5	42.7	42.3



Average Values

w_l = 43.7

w_p = 37.4

w_s = ______

I_p = 6.3

I_f = ______

I_t = ______

Plastic Limit

Trial No.	1	2	3
Container No.	AN	AE	BE
Wt. Sample Wet + Tare	61.1283	63.5344	65.0263
Wt. Sample Dry + Tare	58.6362	60.6781	62.1226
Wt. Water	2.4921	2.8563	2.9037
Tare Container	51.9204	53.0899	54.3916
Wt. of Dry Soil	6.7158	7.5882	7.7310
Moisture Content %	37.1	37.6	37.6

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ______

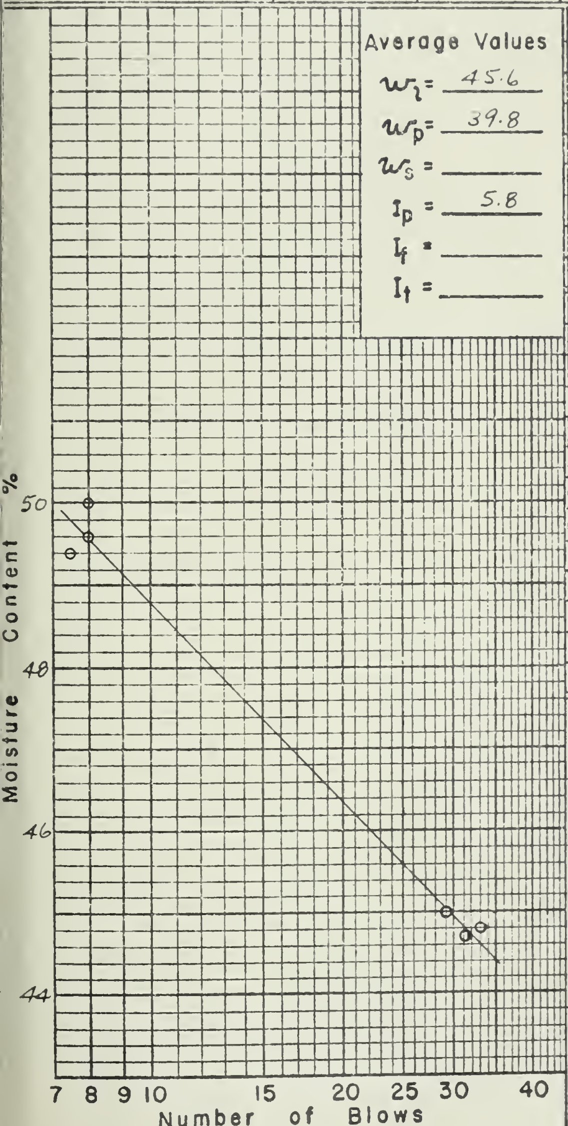
Remarks: CURING TIME 199 HOURS

UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD - #4 & 8 C%
LOCATION	NORMAL PORTLAND
HOLE	DEPTH
TECHNICIAN [illegible]	DATE 4/12/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	33	29	31	8	8	7.5
Container No.	V42	V74	V72	A13	A15	V25
Wt. Sample Wet + Tare	103.94	106.38	106.41	100.34	101.26	116.90
Wt. Sample Dry + Tare	92.63	95.42	95.15	89.89	89.79	106.29
Wt. Water	11.31	10.96	11.26	10.45	11.47	10.61
Tare Container	67.38	71.07	69.97	69.01	66.64	84.86
Wt. of Dry Soil	25.25	24.35	25.18	20.88	23.15	21.43
Moisture Content w%	44.8	45.0	44.7	50.0	49.6	49.5



Average Values

w_l = 45.6

w_p = 39.8

w_s =

I_p = 5.8

I_f =

I_t =

Plastic Limit

Trial No.	1	2	3
Container No.	AN	BE	AE
Wt. Sample Wet + Tare	58.7444	60.7422	59.8772
Wt. Sample Dry + Tare	56.8102	58.9209	57.9553
Wt. Water	1.9342	1.8213	1.9219
Tare Container	51.9204	54.3916	53.0899
Wt. of Dry Soil	4.8898	4.5293	4.8654
Moisture Content %	39.6	40.2	39.5

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V - V_o$			
Shrinkage Limit w_s			

$$w_s = w \left(\frac{V - V_o}{W_o} \times 100 \right)$$

Description of Sample:

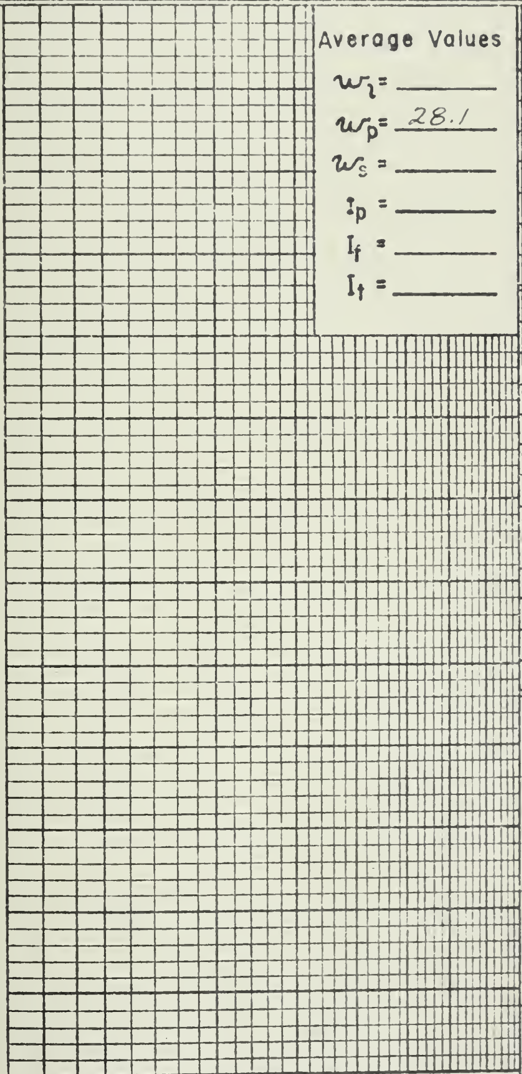
Remarks: CURING TIME 690 HOURS

UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD - #20 & 90
LOCATION	NORMAL PORTLAND
HOLE	DEPTH
TECHNICIAN [illegible]	DATE 17/12/58

Liquid Limit

Trial No.						
No. of Blows						
Container No.						
Wt. Sample Wet + Tare						
Wt. Sample Dry + Tare						
Wt. Water						
Tare Container						
Wt. of Dry Soil						
Moisture Content w%						



Average Values

w_l =

w_p = 28.1

w_s =

I_p =

I_f =

I_t =

Plastic Limit

Trial No.	1	2	3
Container No.	AD-AV	AT	AH
Wt. Sample Wet+Tare	63.0699	63.7352	61.5739
Wt. Sample Dry+Tare	61.0560	61.5172	59.4593
Wt. Water	2.0139	2.2180	2.1146
Tare Container	53.6548	53.7176	52.0623
Wt. of Dry Soil	7.4012	7.7996	7.3970
Moisture Content %	27.2	28.4	28.6

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

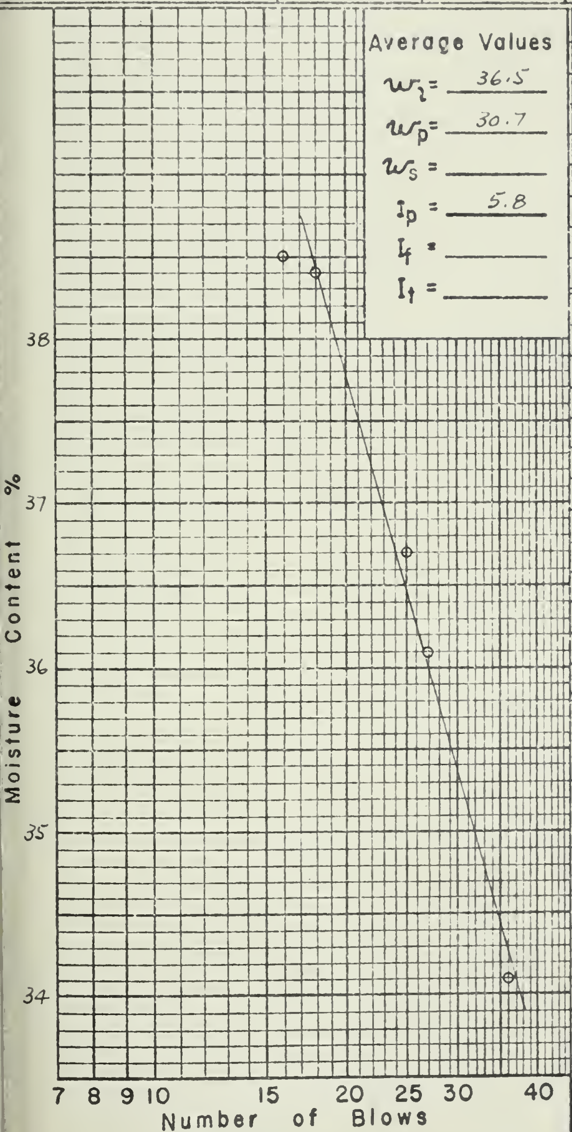
Description of Sample: ______

Remarks: CURING TIME 1 HOUR

UNIVERSITY of ALBERTA DEP'T of CIVIL ENGINEERING SOIL MECHANICS LABORATORY **ATTERBERG LIMITS**	PROJECT SITE SAMPLE Crawford #40 ¢ LOCATION 10% Lime + 20% Fly Ash HOLE / DEPTH TECHNICIAN R. A. H. DATE 23/12/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	35	36	25	27	16	18
Container No.	V24	V74	V41	V46	V49	V37
Wt. Sample Wet + Tare	94.74	86.21	98.14	103.96	94.54	90.18
Wt. Sample Dry + Tare	90.44	82.36	91.23	98.58	88.15	83.65
Wt. Water	4.30	3.85	6.91	5.38	6.39	6.53
Tare Container	77.88	71.07	72.41	83.69	71.56	66.62
Wt. of Dry Soil	22.56	11.29	18.82	14.89	16.59	17.03
Moisture Content w%	19.0	34.1	36.7	36.1	38.5	38.4



Average Values

w_l = 36.5

w_p = 30.7

w_s =

I_p = 5.8

I_f =

I_t =

Plastic Limit

Trial No.	1	2	3
Container No.	BE	28	29.20
Wt. Sample Wet + Tare	63.4687	45.8946	45.7432
Wt. Sample Dry + Tare	61.9237	43.2850	43.9270
Wt. Water	1.5450	2.6096	1.8162
Tare Container	54.3916	36.0319	36.8238
Wt. of Dry Soil	7.5321	7.2531	7.1532
Moisture Content %	x 20.5	36.0	25.4

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample:

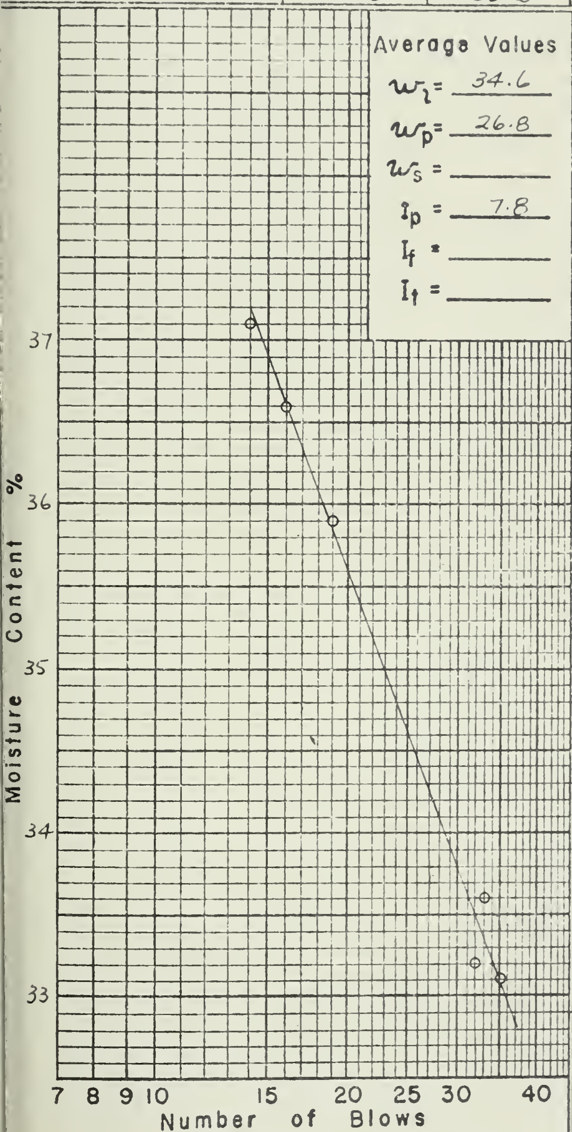
Remarks: Curing Time 1 Hour

UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD — #40 [illegible]
LOCATION	[illegible]% LIME + 2% FLY ASH
HOLE	DEPTH
TECHNICIAN [illegible]	DATE 23/12/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	33	32	35	14	16	19
Container No.	V66	V71	A30	V63	A12	V21
Wt. Sample Wet + Tare	106.83	107.75	104.53	101.53	96.67	104.44
Wt. Sample Dry + Tare	96.65	98.86	96.22	92.39	89.88	96.09
Wt. Water	10.18	8.89	8.31	9.14	6.79	8.35
Tare Container	66.41	72.04	71.10	67.77	71.36	72.81
Wt. of Dry Soil	30.24	26.82	25.12	24.62	18.52	23.28
Moisture Content w%	33.6	33.2	33.1	37.1	36.6	35.9



Average Values

w_l = 34.6

w_p = 26.8

w_s =

I_p = 7.8

I_f =

I_t =

Plastic Limit

Trial No.	1	2	3
Container No.	BK	AM-BJ	BY-BE
Wt. Sample Wet + Tare	59.1565	59.0362	60.3272
Wt. Sample Dry + Tare	57.9345	57.4668	58.9606
Wt. Water	1.2220	1.5694	1.3666
Tare Container	53.2661	51.6700	53.9418
Wt. of Dry Soil	4.6684	5.7968	5.0188
Moisture Content %	26.2	27.1	27.2

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V - V_o$			
Shrinkage Limit w_s			

$$w_s = w \left(\frac{V - V_o}{W_o} \times 100\right)$$

Description of Sample: ________

Remarks: CURING TIME 6 HOURS.

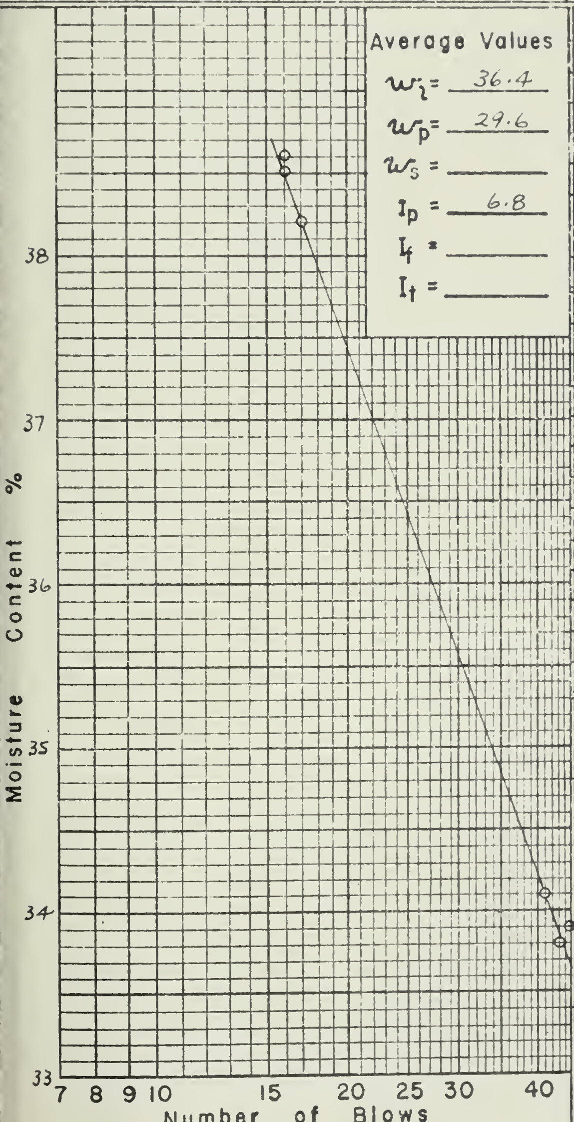
UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD – #4 ⅞
LOCATION	1.0% LIME + 20% FLY. ASH
HOLE	DEPTH
TECHNICIAN [illegible]	DATE 24/12/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	42	43	45	16	16	17
Container No.	V71	A23	V40	V66	V74	V24
Wt. Sample Wet + Tare	95.61	99.95	90.36	95.06	97.60	104.88
Wt. Sample Dry + Tare	89.62	93.07	83.97	87.08	90.22	97.42
Wt. Water	5.99	6.88	6.39	7.98	7.38	7.46
Tare Container	72.04	72.72	65.12	66.41	71.07	77.88
Wt. of Dry Soil	17.58	20.35	18.85	20.67	19.15	19.54
Moisture Content w%	34.1	33.8	33.9	38.6	38.5	38.2



Average Values

w_l = 36.4

w_p = 29.6

w_s = ______

I_p = 6.8

I_f = ______

I_t = ______

Plastic Limit

Trial No.	1	2	3
Container No.	22	AT	AE
Wt. Sample Wet + Tare	46.2921	64.3337	63.0364
Wt. Sample Dry + Tare	43.8888	61.8978	60.7701
Wt. Water	2.4033	2.4359	2.2663
Tare Container	35.7490	53.7176	53.0899
Wt. of Dry Soil	8.1398	8.1802	7.6802
Moisture Content %	29.5	29.8	29.5

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ______

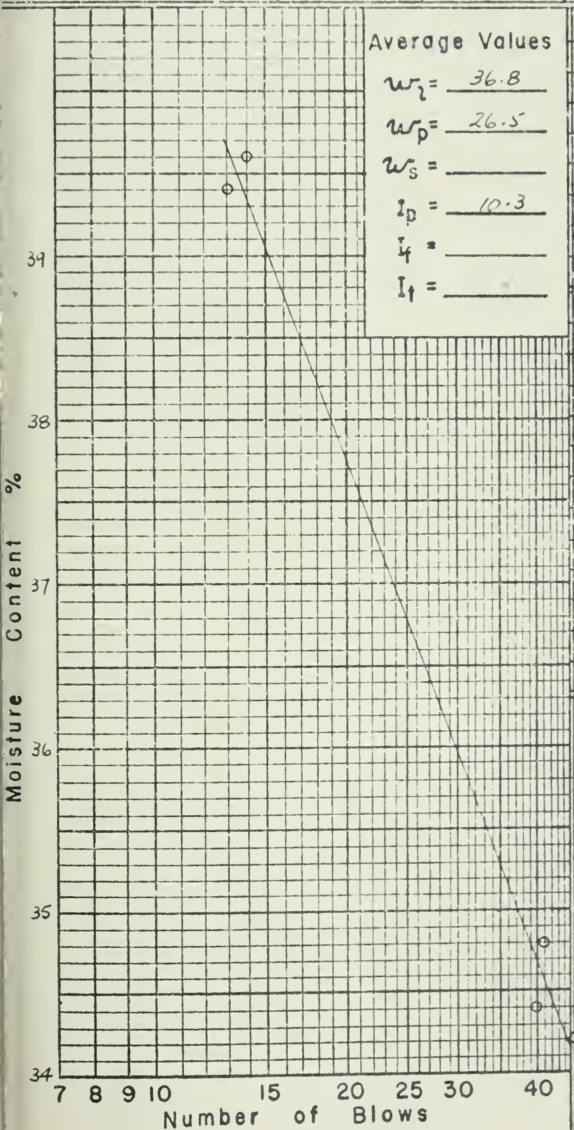
Remarks: CURING TIME 24 HOURS

UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD - #40 ½
LOCATION	1.0% LIME + 2.0% FLY ASH
HOLE	DEPTH
TECHNICIAN	[illegible] DATE 31/12/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	41	40	46	14	13	13
Container No.	V42	V58	V21	V26	V30	V74
Wt. Sample Wet + Tare	110.59	101.95	105.68	106.63	103.96	106.01
Wt. Sample Dry + Tare	99.46	93.67	97.31	97.23	94.13	96.15
Wt. Water	11.13	8.28	8.37	9.40	9.83	9.86
Tare Container	67.38	69.65	72.81	73.51	71.10	71.09
Wt. of Dry Soil	32.08	24.02	24.50	23.72	23.03	25.06
Moisture Content w%	34.8	34.4	34.2	39.6	42.6	39.4



Average Values

w_l = 36.8

w_p = 26.5

w_s = ______

I_p = 10.3

I_f = ______

I_t = ______

Plastic Limit

Trial No.	1	2	3
Container No.	BE	BY-BZ	20-29
Wt. Sample Wet + Tare	60.2903	60.1594	43.8105
Wt. Sample Dry + Tare	59.0610	58.8360	42.3590
Wt. Water	1.2293	1.3234	1.4515
Tare Container	54.3916	53.9418	36.8238
Wt. of Dry Soil	4.6794	4.8942	5.5352
Moisture Content %	26.2	27.1	26.3

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w \left(\frac{V-V_o}{W_o} \times 100 \right)$$

Description of Sample: ______

Remarks: CURING TIME 193 HOURS

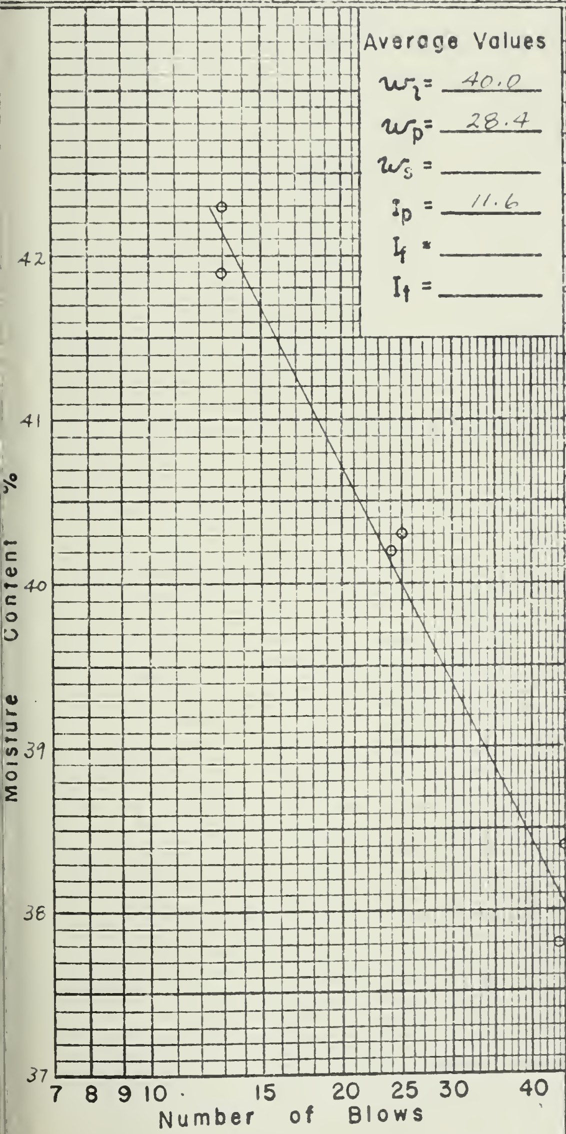
UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD – #40 ξ
LOCATION	1.0% LIME + 20% FLY ASH
HOLE	DEPTH
TECHNICIAN [illegible]	DATE 28/1/59

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	44	45	25	24	13	13
Container No.	V-63	V-6	V42	V66	V49	V68
Wt. Sample Wet + Tare	93.29	100.15	88.88	93.64	95.83	112.95
Wt. Sample Dry + Tare	86.28	93.65	82.71	85.82	88.62	105.32
Wt. Water	7.01	6.50	6.17	7.82	7.21	7.63
Tare Container	67.77	76.74	67.38	66.41	71.56	87.12
Wt. of Dry Soil	18.51	16.91	15.33	19.41	17.06	18.20
Moisture Content w%	37.8	38.4	40.3	40.2	42.3	41.9



Average Values

w_l = 40.0
w_p = 28.4
w_s =
I_p = 11.6
I_f =
I_t =

Plastic Limit

Trial No.	1	2	3
Container No.	23	AE	BW
Wt. Sample Wet + Tare	45.6894	62.4126	63.8337
Wt. Sample Dry + Tare	43.6595	60.4251	61.8955
Wt. Water	2.0299	1.9875	1.9382
Tare Container	36.2967	53.9418	54.7360
Wt. of Dry Soil	7.3628	6.4833	7.1595
Moisture Content %	27.6	* 30.6	27.1

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample:

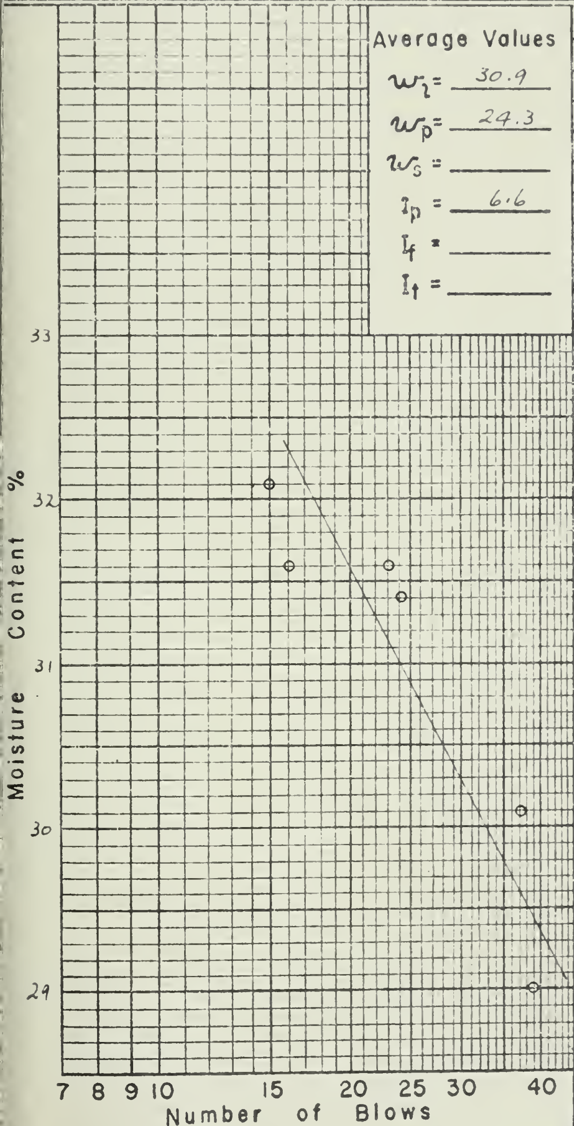
Remarks: CURING TIME 866 HOURS

UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD - #40 ¼
LOCATION	2.0% LIME + 4.0% FLY ASH
HOLE	DEPTH
TECHNICIAN [illegible]	DATE 23 [illegible] 58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	15	16	23	24	31	39
Container No.	V23	V42	A15	A13	V35	V68
Wt. Sample Wet + Tare	110.11	104.17	102.35	104.49	101.58	115.29
Wt. Sample Dry + Tare	100.21	95.33	93.78	96.00	94.45	108.95
Wt. Water	9.90	8.84	8.57	8.49	7.13	6.34
Tare Container	69.34	67.38	66.64	69.01	70.76	87.12
Wt. of Dry Soil	30.87	27.95	27.14	26.99	23.69	21.83
Moisture Content w%	32.1	31.6	31.6	31.4	30.1	29.0



Average Values

w_l = 30.9

w_p = 24.3

w_s =

I_p = 6.6

I_f =

I_t =

Plastic Limit

Trial No.	1	2	3
Container No.	23	22	30
Wt. Sample Wet + Tare	45.8065	46.6803	47.5378
Wt. Sample Dry + Tare	43.9499	44.5436	45.3668
Wt. Water	1.8566	2.1367	2.1710
Tare Container	36.2967	35.7490	36.5148
Wt. of Dry Soil	7.6532	8.7946	8.8520
Moisture Content %	24.2	24.2	24.5

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample:

Remarks: CURING TIME 1 HOUR

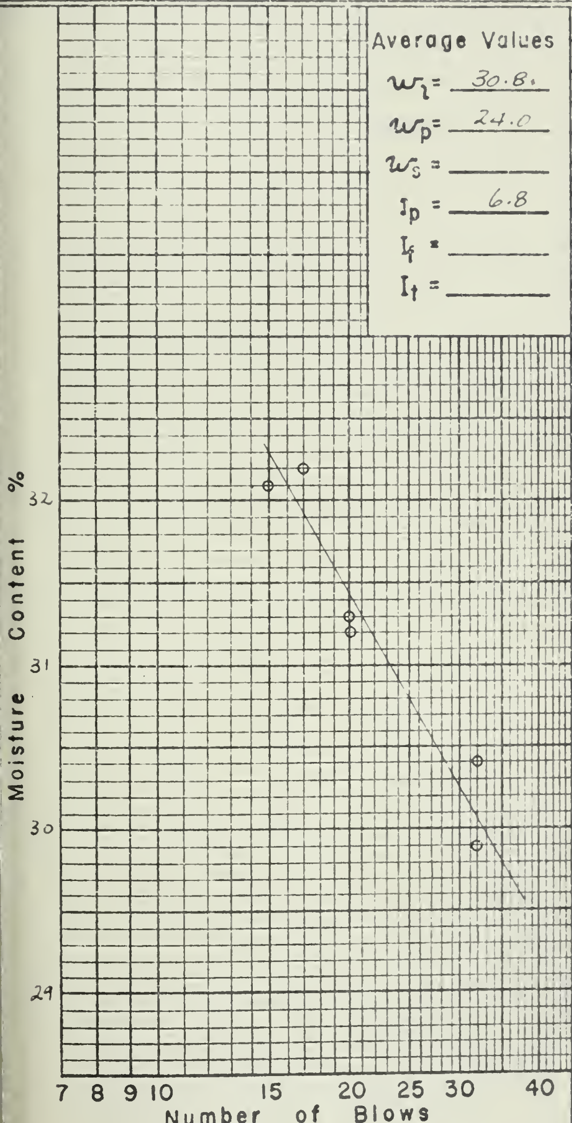
UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	RAWFORD – #4
LOCATION	2.0% LIME + 4.0% FLY-ASH
HOLE	DEPTH
TECHNICIAN [illegible]	DATE 23/12 58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	15	17	20	20	32	32
Container No.	V65	A23	V47	V30	V58	V6
Wt. Sample Wet + Tare	106.24	108.80	96.47	99.01	84.47	108.17
Wt. Sample Dry + Tare	96.92	100.03	88.73	91.90	81.01	100.93
Wt. Water	9.32	8.78	7.74	7.11	3.46	7.24
Tare Container	67.85	72.72	64.01	69.10	69.65	76.74
Wt. of Dry Soil	29.07	27.31	24.72	22.80	11.36	24.19
Moisture Content w%	32.1	32.2	31.3	31.2	30.4 ~~31.2~~	29.9



Average Values

w_l = 30.8

w_p = 24.0

w_s =

I_p = 6.8

I_f =

I_t =

Plastic Limit

Trial No.	1	2	3
Container No.	BG + BA	AH	AE
Wt. Sample Wet + Tare	62.4511	60.0660	62.1845
Wt. Sample Dry + Tare	60.4463	58.5224	60.4438
Wt. Water	2.0048	1.5436	1.7457
Tare Container	52.2528	52.0623	53.0899
Wt. of Dry Soil	8.1935	6.4601	7.3539
Moisture Content %	24.5	23.9	23.7

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample:

Remarks: CURING TIME 6 HOURS

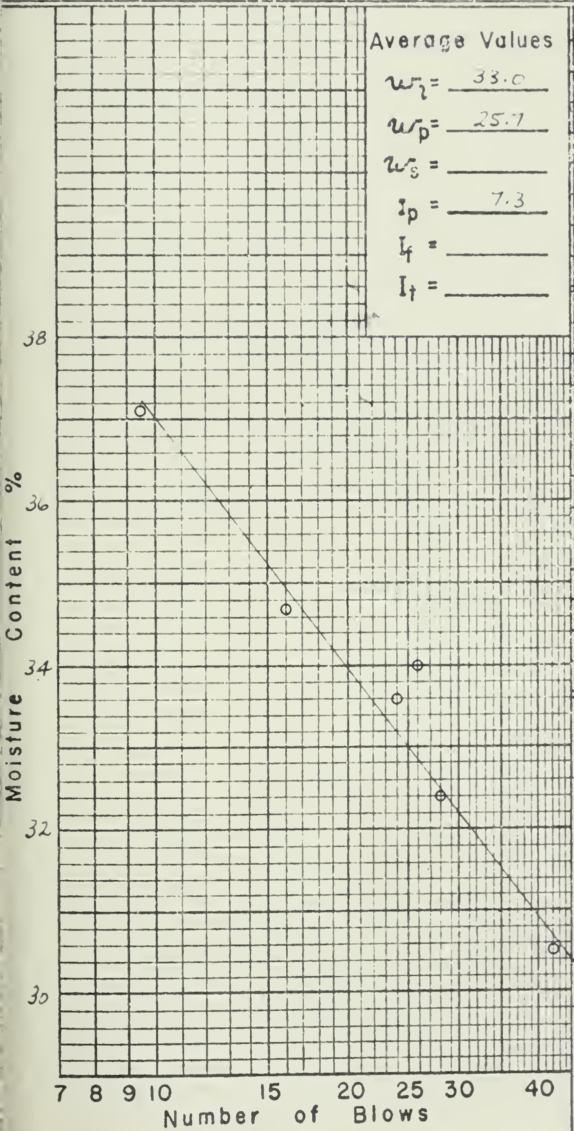
UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

ATTERBERG LIMITS

PROJECT
SITE
SAMPLE CRAWFORD #4
LOCATION 2.0% LIME + 4 % FLY ASH
HOLE DEPTH
TECHNICIAN
DATE 24/12/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	16	24	26	28	42	4½
Container No.	V68	H30	V37	V72	V62	H15
Wt. Sample Wet + Tare	130.07	109.88	108.87	110.62	105.33	103.09
Wt. Sample Dry + Tare	119.00	100.13	98.17	100.67	95.91	93.23
Wt. Water	11.07	9.75	10.70	9.95	9.42	9.86
Tare Container	87.12	71.10	66.62	69.97	65.02	66.64
Wt. of Dry Soil	31.88	29.03	31.55	30.70	30.89	26.59
Moisture Content w%	34.7	33.6	34.0	32.4	30.5	37.1



Average Values

w_l = 33.0
w_p = 25.7
w_s =
I_p = 7.3
I_f =
I_t =

Plastic Limit

Trial No.	1	2	3
Container No.	BK	30	27
Wt. Sample Wet+Tare	60.1623	42.6846	46.4125
Wt. Sample Dry+Tare	58.6904	41.4436	44.7289
Wt. Water	1.4719	1.2410	1.7436
Tare Container	53.2661	36.5148	37.1263
Wt. of Dry Soil	5.4243	4.9288	7.0026
Moisture Content %	27.1	25.2	24.9

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample:

Remarks: CURING TIME 24 HOURS

UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD - #40 [illegible]
LOCATION	2.0% LIME + 4.0% FLY ASH
HOLE	DEPTH
TECHNICIAN [illegible]	DATE 31/12/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	19	21	20	42	42	45
Container No.	V46	V49	A23	V72	V40	V71
Wt. Sample Wet + Tare	119.47	112.06	103.02	104.02	94.68	98.23
Wt. Sample Dry + Tare	109.70	101.01	94.88	95.33	87.20	91.72
Wt. Water	9.77	11.05	8.14	8.69	7.48	6.51
Tare Container	83.69	71.56	72.72	69.97	65.12	72.04
Wt. of Dry Soil	26.01	29.45	22.16	25.36	22.08	19.68
Moisture Content w%	37.6	37.5	36.8	34.3	33.9	33.1

Average Values

w_l = 36.2

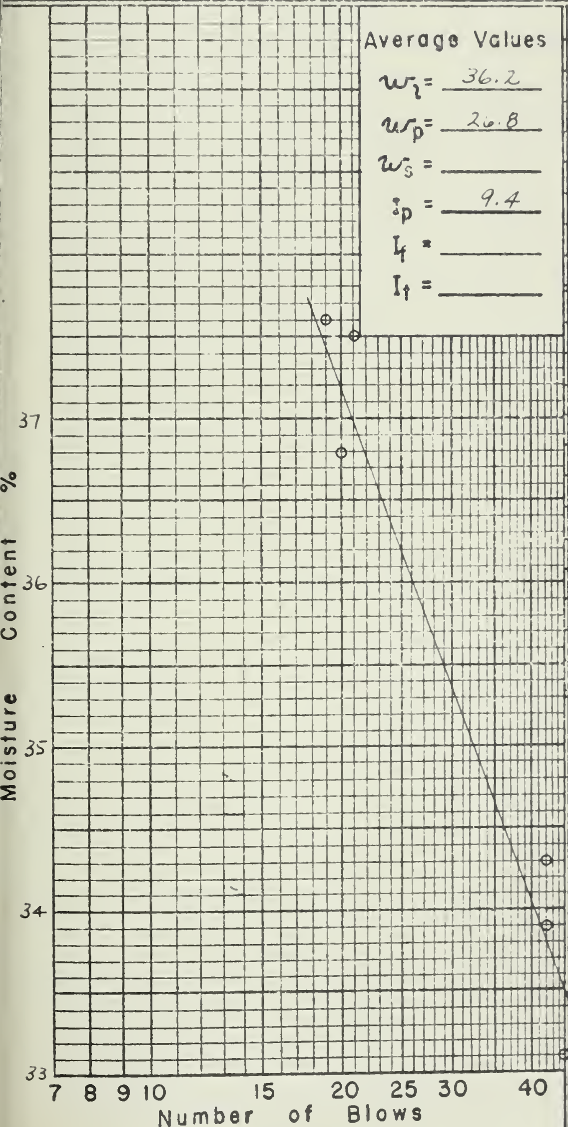
w_p = 26.8

w_s =

I_p = 9.4

I_f =

I_t =



Plastic Limit

Trial No.	1	2	3
Container No.	BL	AM + BJ	BA + BG
Wt. Sample Wet + Tare	62.3322	59.9832	59.8222
Wt. Sample Dry + Tare	60.7301	58.2432	58.2061
Wt. Water	1.6021	1.7400	1.6161
Tare Container	54.7430	51.6700	52.2528
Wt. of Dry Soil	5.9871	6.5732	5.9533
Moisture Content %	26.8	26.5	27.1

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample

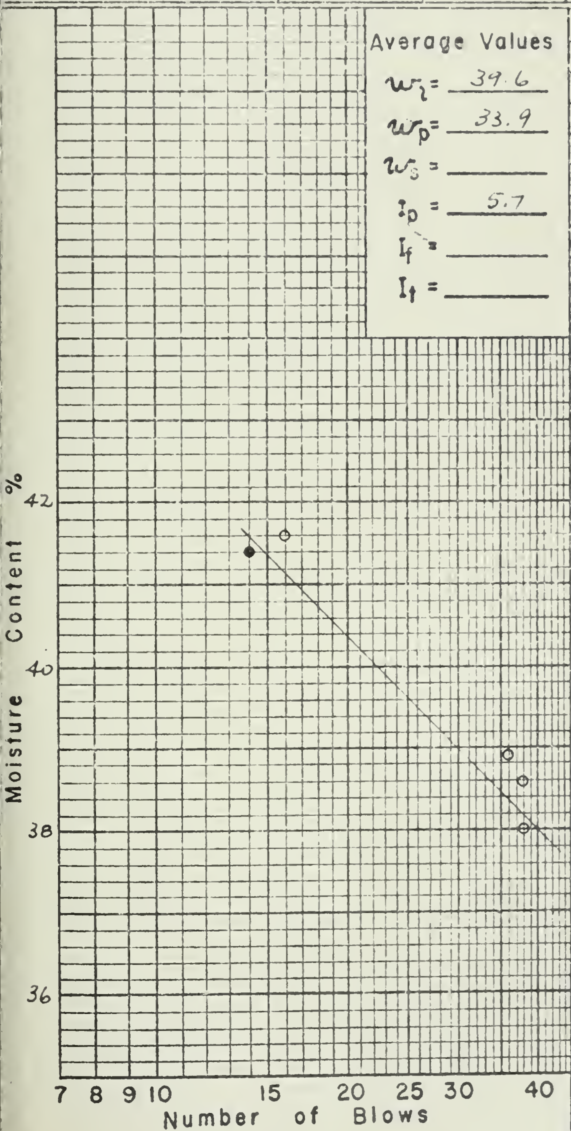
Remarks: CURING TIME 193 HOURS.

UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT
SITE
SAMPLE Crawford — #40 ¢
LOCATION 2.0% Lime + 4.0% Fly Ash
HOLE DEPTH
TECHNICIAN M. L. H. DATE 28/ /54

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	16	14	14	38	38	36
Container No.	A30	V25	V40	V47	V69	V41
Wt. Sample Wet + Tare	113.04	116.74	102.86	103.99	106.71	107.46
Wt. Sample Dry + Tare	100.71	107.41	91.82	92.86	96.44	97.65
Wt. Water	12.33	9.33	11.04	11.13	10.27	9.81
Tare Container	71.10	84.86	65.12	64.01	69.39	72.41
Wt. of Dry Soil	29.61	22.55	26.70	28.85	27.05	25.24
Moisture Content w%	41.6	41.4	41.4	38.6	38.0	38.9



Average Values

w_l = 39.6
w_p = 33.9
w_s =
I_p = 5.7
I_f =
I_t =

Plastic Limit

Trial No.	1	2	3
Container No.	28	BK	AH
Wt. Sample Wet + Tare	46.7973	62.3210	61.2954
Wt. Sample Dry + Tare	44.0856	60.0059	58.9649
Wt. Water	2.7117	2.3151	2.3305
Tare Container	36.0319	53.2661	52.0623
Wt. of Dry Soil	8.0537	6.7398	6.9026
Moisture Content %	33.7	34.3	33.8

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w %			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample:

Remarks: Curing Time 866 Hours

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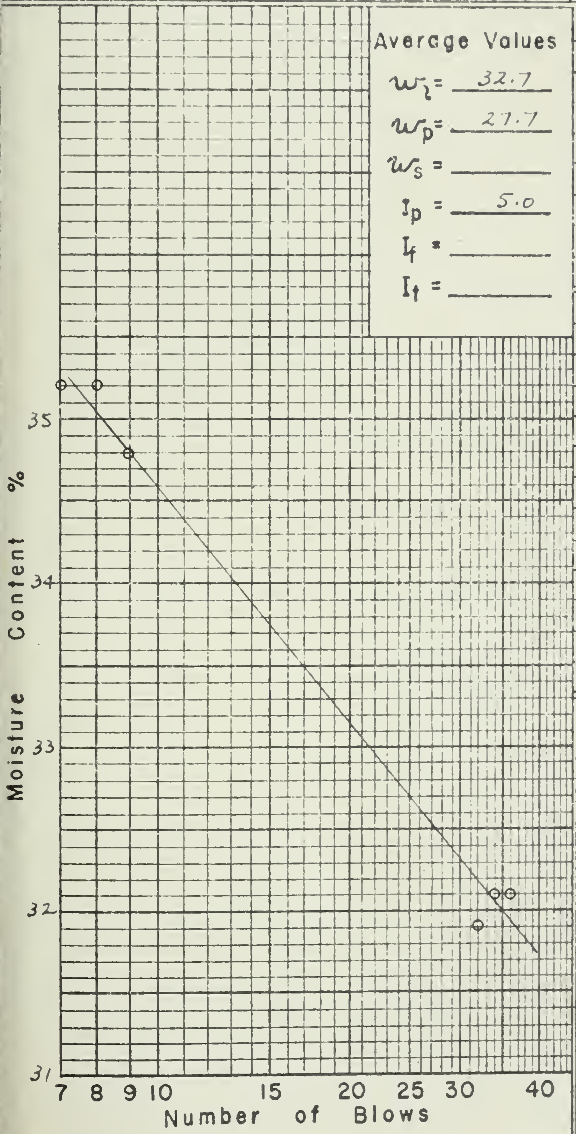
ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD – #40 [illegible]
LOCATION	3.5% LIME + 10% FLY-ASH
HOLE	DEPTH
TECHNICIAN [illegible]	DATE 23/12/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	7	8	9	36	34	32
Container No.	V72	V26	V25	V70	V50	V61
Wt. Sample Wet + Tare	112.58	119.01	123.78	104.01	107.31	99.17
Wt. Sample Dry + Tare	101.50	107.17	113.75	98.70	101.06	91.86
Wt. Water	11.08	11.84	10.03	5.31	6.25	7.31
Tare Container	69.97	73.50	84.86	82.16	81.56	68.90
Wt. of Dry Soil	31.53	33.67	28.89	16.54	19.50	22.96
Moisture Content w%	35.2	35.2	34.8	32.1	32.1	31.9



Average Values

w_l = 32.7

w_p = 27.7

w_s =

I_p = 5.0

I_f =

I_t =

Plastic Limit

Trial No.	1	2	3
Container No.	AD-AV	AT	27
Wt. Sample Wet + Tare	62.6316	63.4491	48.3483
Wt. Sample Dry + Tare	60.6732	61.4371	46.0419
Wt. Water	1.9584	2.0120	2.3064
Tare Container	53.6548	53.7176	37.7263
Wt. of Dry Soil	7.0184	7.7195	8.3156
Moisture Content %	27.8	* 26.0	27.7

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample:

Remarks: CURING TIME 1 HOUR

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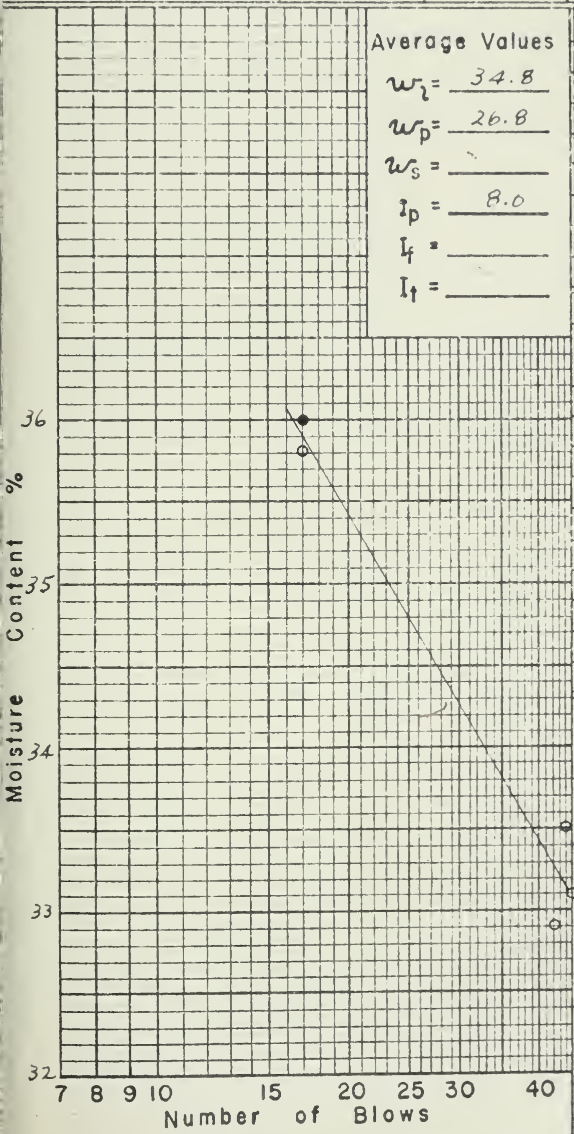
ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD - #4C 4
LOCATION	35% LIME & 70% FLY-ASH
HOLE	DEPTH
TECHNICIAN	DATE 23/12/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	44	45	42	17	17	17
Container No.	V61	V40	A11	V64	V69	V62
Wt. Sample Wet + Tare	106.84	89.58	103.34	91.91	94.21	91.43
Wt. Sample Dry + Tare	99.26	83.50	95.01	85.27	87.64	84.45
Wt. Water	7.58	6.08	8.33	6.64	6.57	6.98
Tare Container	76.66	65.12	69.69	66.77	69.39	65.02
Wt. of Dry Soil	22.60	18.38	25.32	18.50	18.26	19.43
Moisture Content w%	33.5	33.1	32.9	35.8	36.0	36.0



Average Values

w_l = 34.8

w_p = 26.8

w_s =

I_p = 8.0

I_f =

I_t =

Plastic Limit

Trial No.	1	2	3
Container No.	AK-AV	BW	BL
Wt. Sample Wet+Tare	62.5631	64.9009	64.4111
Wt. Sample Dry+Tare	60.7162	62.7378	62.3842
Wt. Water	1.8469	2.1631	2.0269
Tare Container	53.7869	54.7360	54.7430
Wt. of Dry Soil	6.9293	8.0018	7.6412
Moisture Content %	26.6	27.1	26.6

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample:

Remarks: CURING TIME 6 HOURS

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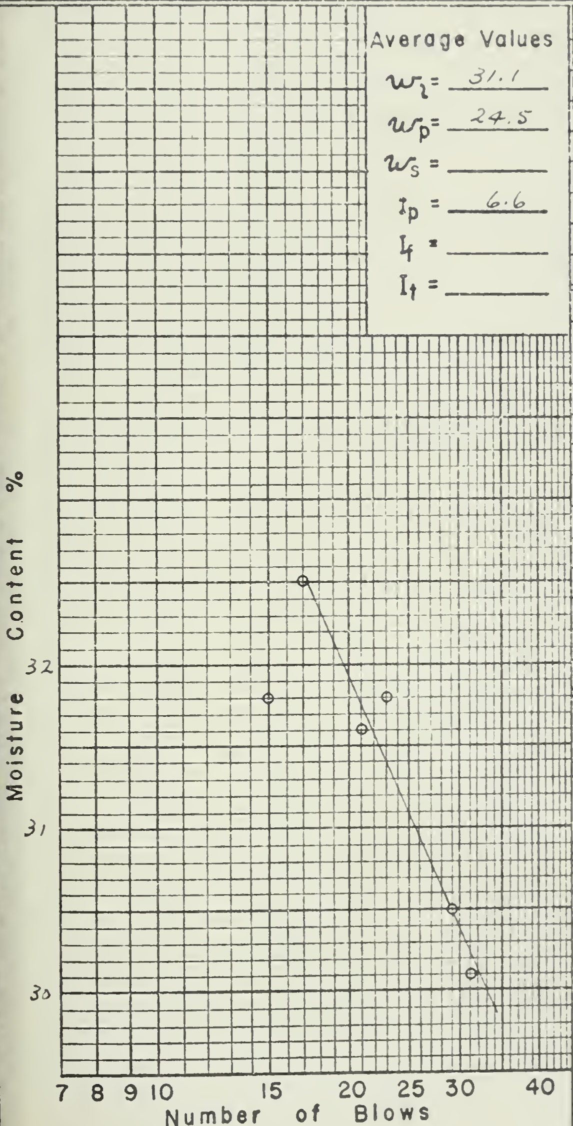
ATTERBERG LIMITS

PROJECT
SITE
SAMPLE CRAWFORD #40 ?
LOCATION 3.5% LIME + 7.0% FLY ASH
HOLE DEPTH
TECHNICIAN [illegible] DATE 24.12.58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	15	17	21	23	29	31
Container No.	A13	V63	V46	V65	V23	V47
Wt. Sample Wet + Tare	98.63	101.01	112.02	97.23	100.88	98.55
Wt. Sample Dry + Tare	91.49	92.85	105.22	90.14	93.52	90.56
Wt. Water	7.14	8.16	6.80	7.09	7.36	7.99
Tare Container	69.01	67.77	83.69	67.85	69.34	64.01
Wt. of Dry Soil	22.48	25.08	21.53	22.29	24.18	26.55
Moisture Content w%	31.8	32.5	31.6	31.8	30.5	30.1



Average Values

w_l = 31.1

w_p = 24.5

w_s =

I_p = 6.6

I_f =

I_t =

Plastic Limit

Trial No.	1	2	3
Container No.	23	28	AL+AV
Wt. Sample Wet+Tare	46.0699	45.1100	60.6718
Wt. Sample Dry+Tare	44.1500	43.3144	59.3020
Wt. Water	1.9164	1.7956	1.3698
Tare Container	36.2967	36.0314	53.6548
Wt. of Dry Soil	7.8533	7.2825	5.6472
Moisture Content %	24.4	24.7	24.3

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample:

Remarks: CURING TIME 24 HOURS

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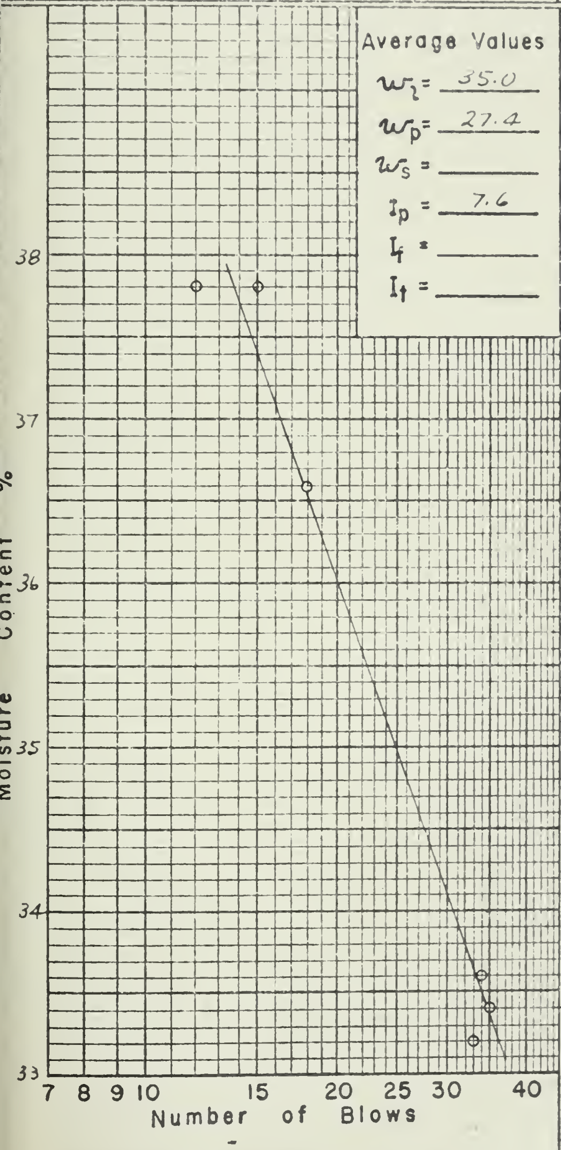
ATTERBERG LIMITS

PROJECT
SITE
SAMPLE Crawford - #40 [illegible]
LOCATION 3.5% Lime + 1.0% Fly-Ash
HOLE DEPTH
TECHNICIAN [illegible] DATE 31/12/58

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	12	16	15	34	35	33
Container No.	V69	V37	V66	H30	A15	V47
Wt. Sample Wet + Tare	110.07	104.49	101.41	105.13	102.41	102.34
Wt. Sample Dry + Tare	98.90	94.36	91.82	96.56	93.45	92.81
Wt. Water	11.17	10.13	9.59	8.57	8.96	9.53
Tare Container	69.39	66.62	66.41	71.10	66.64	64.01
Wt. of Dry Soil	29.51	27.74	25.41	25.46	26.81	28.74
Moisture Content w%	37.8	36.6	37.8	33.6	33.4	33.2



Average Values

w_l = 35.0

w_p = 27.4

w_s =

I_p = 7.6

I_f =

I_t =

Plastic Limit

Trial No.	1	2	3
Container No.	AV-AK	AH	AT
Wt. Sample Wet + Tare	62.5061	60.7318	62.4055
Wt. Sample Dry + Tare	60.6420	58.8885	60.5117
Wt. Water	1.8641	1.8433	1.8938
Tare Container	53.7869	52.0623	53.7176
Wt. of Dry Soil	6.8551	6.8262	6.7941
Moisture Content %	27.2	27.0	27.9

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample:

Remarks: Curing Time 196½ Hours

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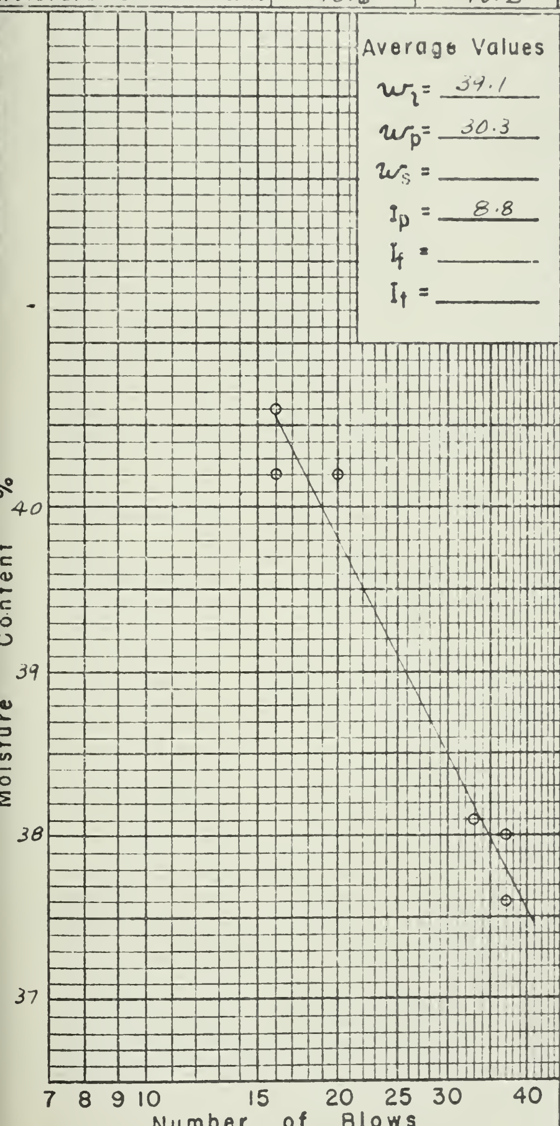
ATTERBERG LIMITS

PROJECT	
SITE	
SAMPLE	CRAWFORD - #4 ξ
LOCATION	3.5% LIME + 10% FLY-ASH
HOLE	DEPTH
TECHNICIAN R. U. M.	DATE 28/1/59

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	16	16	20	33	37	37
Container No.	V65	A15	A11	V30	V35	A13
Wt. Sample Wet + Tare	103.36	103.83	103.22	103.29	103.35	100.05
Wt. Sample Dry + Tare	93.10	93.16	93.60	93.86	94.38	91.57
Wt. Water	10.26	10.67	9.62	9.43	8.97	8.48
Tare Container	67.85	66.64	69.69	69.10	70.76	69.01
Wt. of Dry Soil	25.25	26.52	23.91	24.76	23.62	22.56
Moisture Content w%	40.6	40.2	40.2	38.1	38.0	37.6



Average Values

w_l = 39.1

w_p = 30.3

w_s =

I_p = 8.8

I_f =

I_t =

Plastic Limit

Trial No.	1	2	3
Container No.	30	8L	27
Wt. Sample Wet + Tare	47.2251	63.6968	46.4700
Wt. Sample Dry + Tare	44.7621	61.6051	44.4332
Wt. Water	2.4630	2.0917	2.0368
Tare Container	36.5148	54.7430	37.7263
Wt. of Dry Soil	8.2473	6.8621	6.7069
Moisture Content %	29.9	30.5	30.4

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____________

Remarks: CURING TIME 866 HOURS

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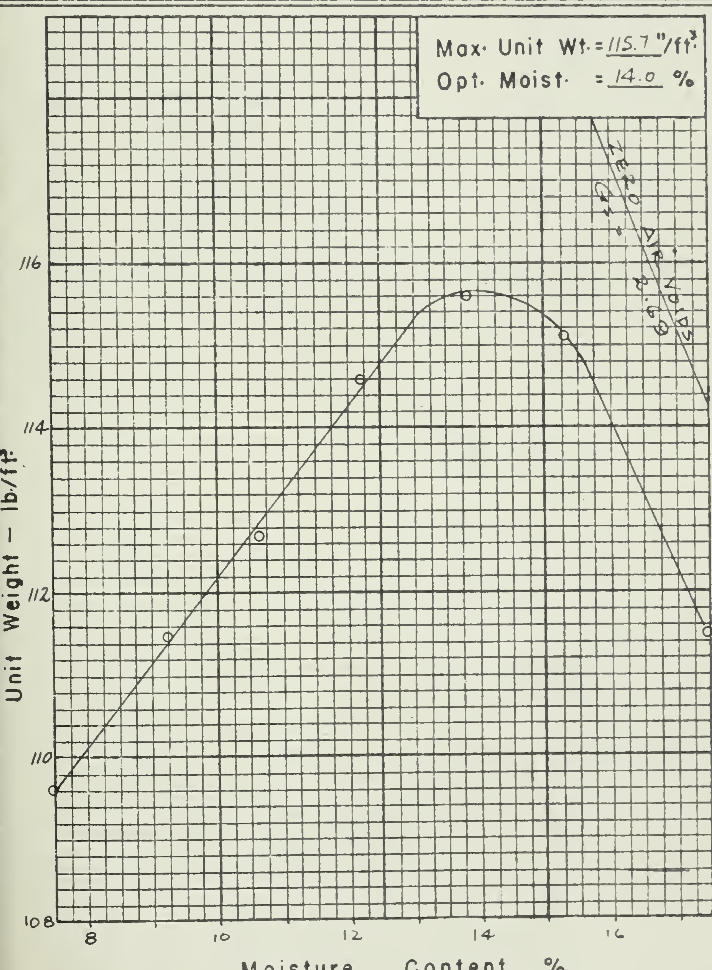
COMPACTION TEST

PROJECT
SITE
SAMPLE Crawford Pit - #4
LOCATION & 1.1% Cement
HOLE DEPTH
TECHNICIAN Millions DATE 19/1/59

Trial Number	1	2	3	4	5	6	7
Unit Weight Determination							
Mold No.							
Wt. Sample Wet + Mold	3517.4	3577.1	3620.1	3679.5	3724.6	3741.3	3716.0
Wt. Mold	1742.8	1742.8	1742.8	1742.8	1742.8	1742.8	1742.8
Wt. Sample Wet	1774.6	1834.3	1877.3	1936.7	1981.8	1998.5	1973.2
Volume Mold	1/30.12	1/30.12	1/30.12	1/30.12	1/30.12	1/30.12	1/30.12
Wet Unit Weight lb./ft.^{3}	117.8	121.8	124.7	128.6	131.6	132.7	131.0
Dry Unit Weight lb./ft.^{3}	109.6	111.5	112.7	114.6	115.6	115.1	111.5
Moisture Content Determination							
Container No.	V72	A13	V25	V42	V26	A15	V23
Wt. Sample Wet + Tare	164.81	158.67	177.63	143.04	157.99	129.88	163.77
Wt. Sample Dry + Tare	158.22	151.10	168.70	134.80	147.71	121.50	149.75
Wt. Water	6.59	7.57	8.93	8.24	10.28	8.38	14.02
Tare Container	69.97	69.01	84.86	63.38	73.50	66.64	69.34
Wt. Dry Soil	88.25	82.09	83.84	67.42	74.21	54.86	80.41
Moisture Content	7.47	9.22	10.65	12.22	13.85	15.28	17.44



Method of Compaction
Std. Proctor Hammer & Mold
3 Layers - 13-13-13 Blows.
Diam. Mold ≃ 4"
Height Mold ≃ 4.6"
Volume Mold 1/30.12
No. of Layers 3
Blows per Layer 13
Ht. of Free Fall 12"
Wt. of Tamper 5.5 lbs.
Shape of Tamping Face O
Description of Sample

Remarks
1.1% Cement in minus #4
= 3.0% Cement in - #40
= 0.45% " " - 3"

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TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE CRAWFORD -3"
LOCATION
HOLE DEPTH
TECHNICIAN [illegible] DATE 28/1/59

Machine Data:-
Machine No. T.O.
Multiplication Factor —
Wt. Loading Block + Piston (gms) 21 Kgm.

Description of Sample: -3" NATIVE GRAVEL NO ADDITIVE COMPACTED AT ≃ 1.5% MOISTURE CONTENT FELT LINER & CIRCUMFERENCE GAUGE USED

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure	(σ_3) Kgm./sq.cm.	0.30					
Length	inches	23 5/8					
Area	sq. cms.	720					
Volume	~~c.c.s.~~ cu. ft.	1.527					
Dry Unit Weight	lbs/cu.ft. γ_d	130.6					
Gs= · Volume Soil Solids	γ_{wet}	140.2		WET SOIL USED = 214 lbs.			
Wt. Tare + Soil + Water at start							
Wt. Tare + Soil + Water at end		14804					
Wt. Tare + Soil		13877					
Number and weight of Tare		1297					
Wt. Soil		12580					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	927					
	Moisture content	7.4					
	Degree of saturation %	70					

Load on Pan	Dial Rdg	Strain	Area	σ_1	Load on Pan	Dial Rdg	Strain	Area	σ_1	Load on Pan	Dial Rdg	Strain	Area	σ_1
LOAD	DIAL RDG.	CIRC. RDG.	STRAIN	ΔC	AREA	$\sigma_1 - \sigma_{III}$	σ_1							
Kgm.	ins.	ins.	%	ins.	cm²	Kgm/cm²	Kgm/cm²							
0	2.919	40	–	–	720	.03	.33							
100	2.910	40	.04	–	720	.17	.47							
200	2.881	40	.14	–	720	.30	.60							
300	2.849	40 1/32	.30	1/32	722	.44	.74							
400	2.804	40 1/16	.49	1/16	723	.58	.88							
500	2.750	40 3/32	.71	3/32	724	.72	1.02							
600	2.692	40 1/8	.96	1/8	725	.86	1.16							
700	2.633	40 3/16	1.21	3/16	728	.99	1.29							
800	2.564	40 1/4	1.50	1/4	730	1.13	1.43							
900	2.485	40 3/8	1.83	3/8	735	1.25	1.55							
1000	2.393	40 1/2	2.22	1/2	740	1.38	1.68							
1100	2.286	40 5/8	2.64	5/8	745	1.50	1.80							
1200	2.122	40 15/16	3.37	15/16	757	1.61	1.91							
1300	1.820	41 1/2	4.65	1 1/2	779	1.70	2.00							
1330	1.510	42 1/4	5.95	2 1/4	810	1.75	2.05							
		FAILURE BY BULGING												

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TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE CRAWFORD – 3" & 0.45%
LOCATION NORMAL PORTLAND
HOLE DEPTH
TECHNICIAN DATE 22/12/58

Machine Data:-
Machine No. T.O.
Multiplication Factor —
Wt. Loading Block + Piston (gms.) 21 Kgm.

Description of Sample:
– 3" NATIVE GRAVEL + 0.45% N.P.
no cure no felt
no circ gauge.

SPECIMEN DATA

Specimen Number		1	2	3	4	5	6
Lateral Pressure (σ₃) Kgm/sq. cm.		0.30					
Length	inches	23 7/8					
Area	sq. cms.	730					
Volume	c.c.s.	1.561					
Dry Unit Weight	lbs/cu.ft. γd	122.0					
Gs= · Volume Soil Solids	γwet	130.0		WET Soil Used = 203 lbs.			
Wt. Tare + Soil + Water at start							
Wt. Tare + Soil + Water at end		5542					
Wt. Tare + Soil		5247					
Number and weight of Tare		774					
Wt. Soil		4473					
Before Test	Weight of water						
	Moisture content						
	Degree of saturation						
After Test	Weight of water	295					
	Moisture content	6.6					
	Degree of saturation %	47					

Load on Pan	Dial Rdg	Strain	Area	σ_1	Load on Pan	Dial Rdg.	Strain	Area	σ_1	Load on Pan	Dial Rdg.	Strain	Area	σ_1
LOAD	DIAL RDG.	STRAIN	AREA	$\sigma_1 - \sigma_{III}$	σ_1									
Kgm.	ins.	%	sq.cm	Kgm/cm²	Kgm/cm²									
0	1.013	–	730	·03	·33									
100	1.013	–	"	·16	·46									
200	1.013	–	"	·30	·60									
300	1.013	–	"	·44	·74									
400	1.012	–	"	·58	·88									
500	1.007	02	"	·71	1.01									
600	0.995	·08	"	·85	1.15									
700	0.984	·12	731	·99	1.29									
800	0.972	·17	731	1.12	1.42									
900	0.962	·21	731	1.26	1.56									
1000	0.951	·26	732	1.40	1.70									
1100	0.939	·31	732	1.53	1.83									
1200	0.928	·35	732	1.67	1.97									
1300	0.912	·42	733	1.80	2.10									
1400	0.891	·51	733	1.94	2.24									
1500	0.854	·66	735	2.07	2.37									
1550	0.815	·82	736	2.14	2.44									
1600	0.740	1.14	738	2.20	2.50									
1633	0.620	1.64	742	2.23	2.53									
		FAILURE		BY	BULGING									

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TRI-AXIAL COMPRESSION

PROJECT
SITE
SAMPLE Crawford -3" & 0.45%
LOCATION Normal Portland
HOLE 1 DEPTH
TECHNICIAN [illegible] DATE 29/12/58

Machine Data:-
Machine No. T.C.
Multiplication Factor —
Wt. Loading Block + Piston (gms.) 21 Kgm

Description of Sample: -3" Native Gravel + 0.45% N.P. Compacted at 6.1% Moisture Content. Saturated in 12 hrs by Vacuum

SPECIMEN DATA

Specimen Number			1	2	3	4	5	6
Lateral Pressure		(σ3) Kgm/sq cm	0.30					
Length		inches	24 1/4					
Area		sq. cms.	730					
Volume		c.c.s. cu ft	1.584					
Dry Unit Weight		lbs/cu.ft. γd	124.7					
Gs= · Volume Soil Solids		γwet	132.1		WET SOIL USED = 210 lbs.			
Wt. Tare + Soil + Water at start								
Wt. Tare + Soil + Water at end			7698.0					
Wt. Tare + Soil			7020.0					
Number and weight of Tare			771.6					
Wt. Soil			6248.4		NO FELT NO CIRC. GAUGE.			
Before Test	Weight of water							
	Moisture content		6.1					
	Degree of saturation							
After Test	Weight of water		678.0					
	Moisture content		10.8					
	Degree of saturation		84					

Load on Pan	Dial Rdg	Strain	Area	σ1	Load on Pan	Dial Rdg	Strain	Area	σ1	Load on Pan	Dial Rdg	Strain	Area	σ1
LOAD	DIAL RDG	STRAIN	AREA	σ1 - σIII	σ1									
Kgm	ins	%	cm²	Kgm/cm²	Kgm/cm²									
0	0.717	–	730	.03	.33									
50	.716	–	730	.10	.40									
100	.715	.01	730	.17	.47									
150	.713	.02	730	.23	.53									
200	.712	.02	730	.30	.60									
250	.710	.03	730	.37	.67									
300	.708	.03	730	.44	.74									
350	.706	.05	730	.51	.81									
400	.702	.06	730	.58	.88									
450	.697	.08	730	.65	.95									
500	.692	.10	730	.71	1.01									
550	.684	.14	731	.78	1.08									
600	.676	.17	731	.85	1.15									
650	.665	.22	731	.92	1.22									
700	.651	.28	732	.99	1.29									
750	.634	.35	732	1.05	1.35									
800	.607	.46	733	1.12	1.42									
850	.515	.84	734	1.18	1.48									
887	.130	2.45	748	1.21	1.51	FAILURE BY BULGING								

UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

SIEVE ANALYSIS

PROJECT
SITE
SAMPLE CRAWFORD FROM
LOCATION TRIAXIAL TEST
HOLE [illegible] DEPTH
TECHNICIAN [illegible] DATE

Total Dry Weight of Sample 20806	Sieve No.	Size of Opening Inches	Size of Opening Mm.	Weight Retained gms.	Total Wt Finer Than gms.	Percent Finer Than	% Finer Than Basis Orig. Sample
Initial Dry Weight Retained No. 4							
Tare No.		3		—	20806		100
Wt. Dry + Tare		1 1/2		1393	19413		93
Tare		3/4	19·10	3776	15637		75
Wt. Dry		3/8	9·52	3334	12303		59
	4	·185	4·76	3429	8874		42.6
Passing	4						
Initial Dry Weight							
Passing No. 4	10	·079	2·000	2859	6015		28.8
Tare No.	20	·0331	·840				
Wt. Dry + Tare	40	·0165	·420	2438	3577		17.1
Tare	60	·0097	·250				
Wt. Dry	100	·0059	·149				
	200	·0029	·074	1228	2349		11.2
Passing	200						

Description of Sample

Time of Sieving

Method of Preparation

Remarks